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GIS as a Tool to Assess Heritage Risk: A Case Study in Frijoles Canyon, Bandelier National Monument

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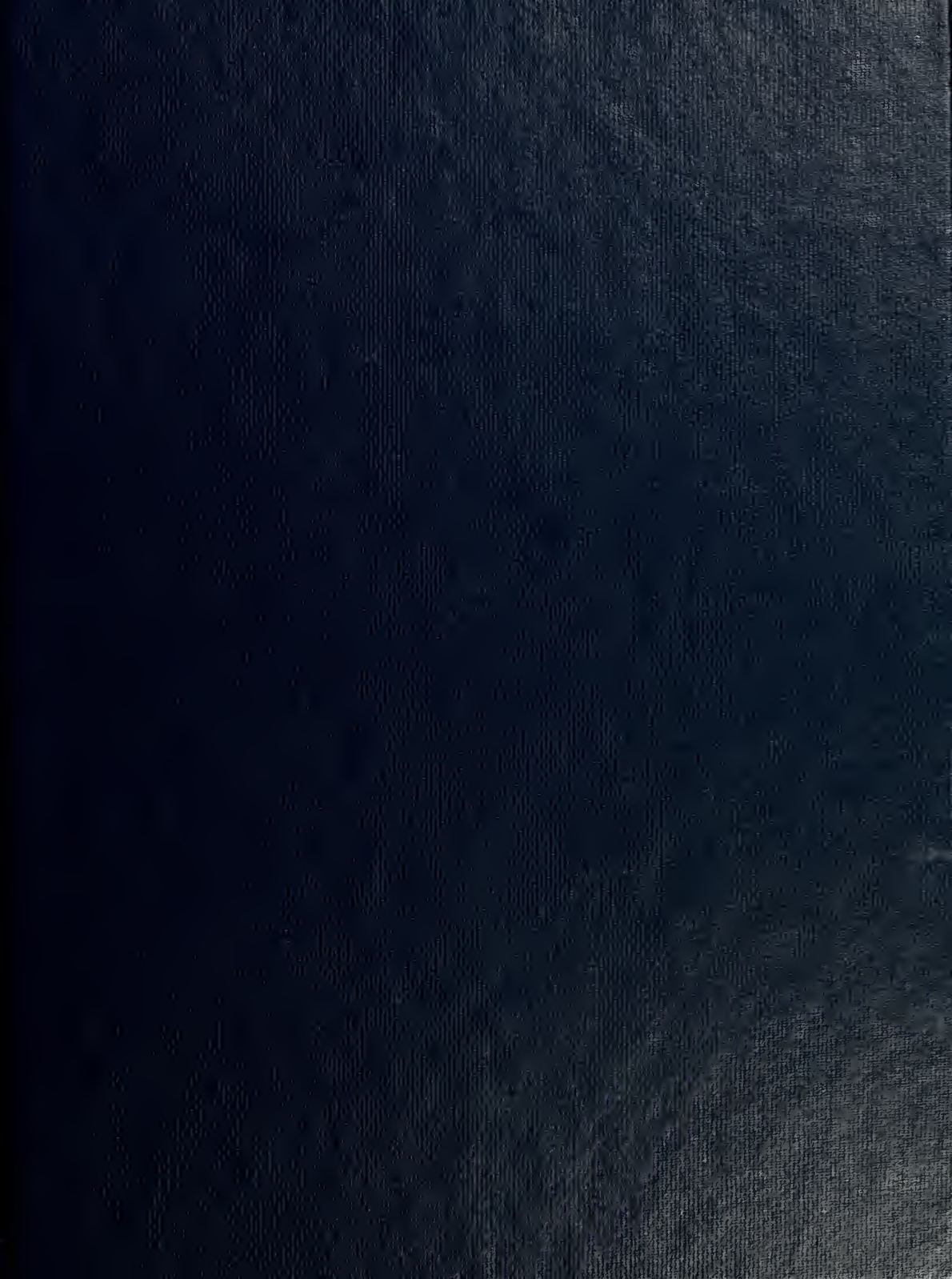
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**GIS AS A TOOL TO ASSESS HERITAGE RISK:
A CASE STUDY IN FRIJOLES CANYON, BANDELIER NATIONAL MONUMENT**

Sophia C. Middlebrook

A THESIS

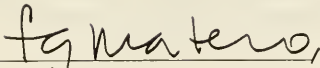
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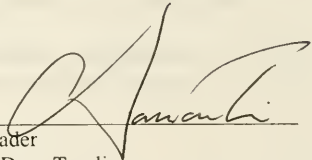
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MASTER OF SCIENCE

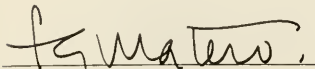
2003



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1

PROJECT INTRODUCTION

Bandelier National Monument, located in north central New Mexico, encompasses 32,727 acres of wilderness and cultural sites and is significant for both natural resources and cultural heritage. Long considered an important site by archaeologists, tourists, Native Americans, and cultural resource managers alike, no systematic survey exists that assesses current condition of cultural resources, outlines conservation treatment priorities, and compares evaluations of significance. In June of 1997, Bandelier National Monument began a multi-year project to develop and implement a conservation plan for the 1,008 ancestral puebloan cliff dwellings located within Frijoles Canyon. Known as C.I.T.A. (Conserve Indigenous Troglodytic Architecture), the three-phase project brings together the National Park Service, the Museum of New Mexico, and the University of Pennsylvania's Architectural Conservation Laboratory with funding from the Getty Grant Program. The primary goals of the project are to combine conservation planning,

condition assessments, site documentation, and treatment with practical training and education.

Participants in Phase one of the project, completed in early 2002, gathered records of past conservation treatments and stabilization reports and designed documentation and treatment protocols. This thesis forms a component of Phase two of the project, begun in February, 2002, which uses documentation and site analysis to develop a conservation plan for the Frijoles Canyon ancestral cliff dwellings. During the summer of 2002, graduate students from the University of Pennsylvania and Native American pueblo students began a detailed condition and significance assessment of the cliff dwellings within Frijoles Canyon. The summer field assessments, together with locational data collected in one sample area of Frijoles Canyon, form the basis of this thesis. In this thesis, I will test whether a Geographic Information System (GIS) serves as a useful tool with which to analyze the relationship between physical context and existing conditions, to assess structural risks in the cliff dwellings in Bandelier National Monument.

Chapter 1 discusses the pivotal and evolving notions of “value” and “risk” in the fields of cultural resource management and architectural conservation. Significance ratings are critical to assigning treatment priority, and significance derives from values associated with a site. Ultimately, given limited resources, conservators and resource managers must prioritize treatment and develop a system of “conservation triage,” in which the highest

priority resources are conserved first. Emerging management principles link “risk” to values and priorities; Chapter 1 includes an examination of the role of risk evaluation in conservation planning. GIS can aid in extracting value and in understanding conditions that cause risk. However, it is critical to note that “GIS systems are not in themselves a method of value elicitation; they are a tool for organization and analyzing data in the service of planning and management.”¹ While GIS is a powerful tool, it relies on the expertise of conservators who understand the physical and social layers inherent in any heritage site, and who ultimately assign value and assess factors that contribute to risk.

A survey of recent conservation literature and projects illustrates that computer technology can be applied to the traditional condition assessment in order to more effectively understand and interpret information collected in the field. Database development has allowed cultural resource managers to create relational webs that correlate condition with features. Digital imaging and computer aided drafting (CAD) programs can be used to create graphic displays of existing condition, and are often used to produce extremely accurate baseline data to which future assessments can be added or compared. Digitally compiled condition graphics allow increased flexibility, as well as a method of examining change over time. In Chapter 2 I will explore the role of GIS as an addition digital tool that can aid in cultural resource management. I will outline how a

¹ Randall Mason, “Assessing Values in Conservation Planning: Methodological Issues and Choices,” *Assessing the Values of Cultural Heritage*, Marta de la Torre, ed., (Getty Conservation Institute: Los Angeles, 2002) page 21.

GIS can be combined with photography, CAD, and database programs to further enhance the accuracy and efficiency of the conservation plan. The GIS will be used to examine the site at multiple scales, to develop a Priority Treatment Schedule for the cavates, and later adapted to the needs of researchers, managers, conservation technicians, and visitors to the site. In addition, the use of GIS will serve as a model for preserving similar cavate pueblos within the Pajarito Plateau, and for organizations managing similar traditional troglodytic architecture.²

This thesis will present the ways in which GIS can serve as a useful tool in Cultural Resource Management (CRM), and will outline several recent projects that have applied GIS technology to specific site preservation and architectural conservation problems. The cliff dwellings located within Frijoles Canyon provide an excellent case study in which to test whether GIS can be used as to evaluate risk and to understand relationships between existing physical features and condition. The site is significant on multiple scales, from individual finishes schemes within cave dwellings, to the larger landscape of the Bandelier wilderness area and Frijoles Canyon. The location, history, and geology of the site will be examined in Chapter 3. In addition, the data collection and field methods will be described, as well as a detailed description of the field condition survey form used by the field school.

² Angelyn Bass Rivera, "World Monuments Watch 2004 Nomination Form," (January, 2004), page 6.

Chapter 4 will use the GIS to analyze factors that put the site at risk. This section of the thesis will establish a series of cause and effect relationships between the location and context of each room surveyed. Finally, the GIS will be used to analyze the existing combinations of context and conditions to assess future risk, in order to develop a conservation treatment schedule for conservators.

All phases of research for this thesis were conducted with the support and assistance of architectural conservators and field school participants at Bandelier National Monument. A primary goal of the field work for this thesis was to create a digital base map of the case study area in order to build a framework for future, more detailed analysis that may use a GIS. The base map and all data displays have been provided to the Park Service, and the GIS will be used as a tool for future project planning by cultural resource managers at Bandelier.

This thesis will affirm the fundamental role of field condition surveys in any preservation plan. In addition, I will assert the utility of the condition survey as way to evaluate risk, to assign treatment priority, and to understand links between existing condition and future performance in order to initiate preventive conservation treatments for the excavated cliff dwellings at Bandelier National Monument.

2

VALUE, RISK, AND CONSERVATION TRIAGE

A successful site conservation tactic, which may be defined as a technique employed to achieve a goal, preserves a cultural resource by protecting the values associated with the site, as well as by minimizing threats to its physical fabric. The “value,” of cultural heritage is composed of a resource’s worth (utility, importance, or merit) as well as the principles and qualities that make it desirable. The goal, in other words, is to preserve the tangible and intangible aspects of the heritage monument or site. Value can derive from the historical, social, and physical contexts of the site, while the natural and cultural situation may place values and fabric in danger. Threats, which are understood as indications of impending danger, accumulate to produce risk, a set of circumstances that create the possibility of total loss of a cultural resource.

In this chapter, I will examine both the role of risk in conservation management and how significance is assigned to heritage sites. I will review ways in which national and international heritage conservation and cultural resource management organizations and

charters address value and understand – and use – risk. Ways in which perceptions of value and indicators of risk can be incorporated in a condition survey and assessment, included in a GIS, and considered in treatment planning will be addressed throughout this thesis.

What is Valuable?

The American Institute for Conservation of Historic and Artistic Works (AIC) identifies three objectives that are achieved through the research and documentation stage of a conservation program in its *Code of Ethics and Guidelines for Practice*:

- To establish the condition of cultural property;
- To add to the professional body of knowledge and therefore aid future treatment programs;
- To aid stewards and managers in the appreciation of a property by enhancing the overall understanding of the resource's artistic, philosophical, and physical characteristics.³

Conservation decisions, such as treatment priority, are based not only on physical condition or the site's state of conservation, but also on how treatment actions will impact a site, and how much society values the property. In order to realize the three goals outlined by the AIC, the site documentation process requires input from multiple sources and disciplines.

³ American Institute for the Conservation of Historic and Artistic Works, *Code of Ethics and Guidelines for Practice*, Guideline 24, available at <http://aic.stanford.edu/pubs/ethics.html>.

The *Burra Charter*, written by Australia's branch of the International Council on Monuments and Sites (ICOMOS), asserts that any conservation or preservation project should begin with physical and archival research. The research phase culminates in a "Statement of Significance," which integrates scientific investigation, contemporary site context, and cultural significance: "[The] written statement of conservation policy must be professionally prepared setting out the cultural significance, physical condition and proposed conservation process together with justification and supporting evidence, including photographs, drawings and all appropriate samples."⁴ The synthesized statement of significance provides a reference of priorities throughout the conservation planning and implementation process.

The role of "cultural significance" is central in the charters and guidelines of national and international organizations in the field of cultural resource conservation such as ICOMOS and AIC, yet the term is difficult to define or quantify. Definitions of value and significance often form the crux of contemporary conservation debates. What factors contribute to a site's value? Cultural and national traditions, expectations of authenticity, historical and aesthetic significance, financial worth, political importance, educational merit, and spiritual connection all determine the value of place and must be considered. Conservation is often practiced in publicly held or appreciated sites; thus to ignore any one of these factors places the entire conservation program in jeopardy. This is

⁴ Australia/ICOMOS, *The Burra Charter*, Article 25.

particularly true ancestral Puebloan sites in the American Southwest under federal management, by organizations such as the National Park Service (NPS), the Bureau of Land Management (BLM), and the National Forest Service (NFS). Parks and Monuments such as Bandelier National Monument, Chaco Culture National Historic Site, and Mesa Verde National Park are layered with significance that derives from architectural and archaeological ruins, tourism appeal, natural resources, and the continued veneration of the sites by surviving Native American Pueblo cultures.

Can significance be measured in any scientific way that excludes contemporary cultural bias? In the nearly four decades since ICOMOS adopted the *International Charter for the Conservation and Restoration of Monuments and Sites*, known as the *Venice Charter*, critics charge that Western values and traditions too often determine what constitutes “significant.” While the *Venice Charter* states the need to consider cultural context when estimating significance or planning for treatment intervention, by the mid 1990’s conservation professionals sought new standards that could provide a framework to better protect indigenous and non-Western cultural artifacts and sites. Reports such as the *Nara Document on Authenticity*, written by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Committee in 1994, seek to recognize the difficulty in assigning value based on a static set of international criteria. In order to protect a diverse body of international monuments and sites, the *Nara Document* proposes a measure of authenticity (defined in this case as true to a specific time or

place), to be determined in each member country, as a means to define “value.” Article

11 explains:

All judgments about values attributed to cultural properties as well as the credibility of related information sources may differ from culture to culture, and even within the same culture. It is thus not possible to base judgments of values and authenticity within fixed criteria. On the contrary, the respect due to all cultures requires that heritage properties must be considered and judged within the cultural contexts to which they belong.”⁵

The *Nara Document* does insist on judgments of value and authenticity, yet acknowledges cultural differences, and proposes that significance be defined within a site’s cultural – national, religious, tribal – context.

Social and cultural shifts have forced international charters that guide conservation decisions to develop through time; working documents such as the *Venice Charter*, the *Burra Charter*, and the *Nara Document* have themselves become part of the record of change in international heritage conservation. When considered as a group, the three charters provide insight to the role of national and cultural identity in conservation planning. They reveal an evolving definition of value for conservation policy: as policy has shifted, so too have the judges of heritage value. The line between art history and technical conservation is no longer as distinct as it was in the nineteenth and early twentieth century; in the past, “experts fixed the value of things, and then conservators

⁵ UNESCO World Heritage Committee, *The Nara Document on Authenticity*, Article 11.

fixed those things materially.”⁶ Heritage conservation as a distinct field has emerged from the disciplines of art and architectural history, regional planning, and material science. Architectural conservators are now compelled to assess value in addition to prescribe treatment.

In his essay “The Modern Cult of Monuments: Its Essence and Its Development,” Alois Riegl begins to expand an art historical approach to value by creating categories of worth: artistic, or aesthetic, value and historical value. Critics of art assign the artistic value to an object or site, and historians describe the historical value. These two categories are distinct and clear. Riegl argues that artistic value, a subjective measure, is intrinsic in the formal and physical qualities of the site. Artistic value does not change through time unless mechanisms of decay alter physical form. Historic value, however, is anchored in contemporary interpretations of past events, and necessarily changes as interpretations change. According to this understanding of historic value, anything – a work of art, an archaeological site, a torn off shred of paper – can be considered “historic” since it once existed and can never exist again. As Riegl states, “...everything that once was forms an irreplaceable and inextricable link in a chain of development. Or, in other words: everything that succeeds was conditioned by what came before and would not have

⁶ Randall Mason, “Assessing Values in Conservation Planning: Methodological Issues and Choices,” *Assessing the Values of Cultural Heritage*, Marta de la Torre, ed., (Getty Conservation Institute: Los Angeles, 2002) page 19.

occurred in the manner in which it did if not for those precedents.”⁷ Riegl cites additional values, such as the “use value,” and “newness value” which may also be considered as criteria for preservation.

Riegl’s (perhaps) tongue-in-cheek observation highlights the selection process inherent in naming specific sites “valuable.” In order to construct workable parameters within which to establish historic significance, stewards of cultural heritage must cull those sites and objects that represent “striking stages in the development of a particular branch of human activity.”⁸ The documentation and assessment process, outlined by both the AIC and ICOMOS provides a format by which to enumerate a long list of values from which to create a hierarchy of values to protect in the preservation plan.

In his study “Assessing Values in Conservation Planning: Methodological Issues and Choices,” Randall Mason expands Riegl’s value categories – historic and aesthetic – and adds spiritual, educational, political, and economic values to the list of primary sources of a site’s significance.⁹ This broader understanding of value recognizes that Native American tribal sites, for example, may possess values that would be undetected (and ultimately unprotected) by early conservation standards. By considering more sources of

⁷ Alois Riegl, “The Modern Cult of Monuments: Its Essence and Its Development,” *Historical and Philosophical Issues in the Conservation of Cultural Heritage*, Nicholas Stanley Price, M. Kirby Talley, Jr., and Alessandra Melucco Vaccaro, eds, (Getty Conservation Institute: Los Angeles, 1996), page 70.

⁸ Riegl, page 70.

⁹ Mason, page 10.

value in the site planning process, the method of creating a hierarchy of values must include methods to prioritize them.

Adequate conservation planning now relies on a multidisciplinary understanding of the site; as Mason notes, resource managers must “cast a wider net” and look to related fields when investigating methodologies for preservation planning. Borrowed elements from fields such as environmental management or city planning can provide new ways to see and document a historic site:

Conservation professionals have traditionally been very skilled in looking at certain contexts of heritage – relating to physical deterioration, environmental conditions, and other physical factors; or to art historical narratives and aesthetic canons – and have developed methodologies and tools for analyzing these contexts. But an understanding of heritage values in the fullest sense requires that conservation professionals cast a wider net and consider more and different contexts of conservation – economic, cultural, and political.¹⁰

Architectural conservators are trained to read physical condition, yet as conservation policy encompasses more complete notions of “site” to include diverse representations of value, resource management faces increased pressure. In order to integrate physical condition assessments with “management context assessments,” as suggested by Mason, the cultural capital – in addition to the material form – inherent in a site can be considered. David Throsby illustrates this method in his essay “Cultural Capital and Sustainability Concepts in the Economics of Cultural Heritage,” with the example of

¹⁰ Mason, pages 14-15.

Ayer's Rock in Australia.¹¹ Ayer's Rock, or Uluru, is culturally valued by indigenous and non-indigenous people. It embodies aesthetic and spiritual significance, and provides a sense of national identity to the traditional, aboriginal "owners," as well other Australians. In addition, Ayer's Rock provides a tangible, historical link to Aboriginal culture. Establishing the cultural capital of the site in turn heightens its economic value. Throsby points out that cultural capital is significant in determining economic value as "individuals...reveal their willingness to pay for the embodied cultural content of this asset by offering a price higher than that which they would offer for the physical entity alone."¹² In other words, the cultural significance of the site, based on its standing as a record of an indigenous culture, takes precedence to the aesthetic value of the rock itself. This notion of cultural capital, or worth, is very similar to the significance of archaeological sites in the American Southwest: cliff dwellings at Bandelier National Monument – the case study used in this thesis – stand as a physical record of ancient Pueblo societies; the integrity of that record lends significance to the site as a whole. The process of assessing heritage value leads to a treatment and management program designed to conserve the maximum values of a site. As Riegl, Mason, and ICOMOS have articulated, "value" should be understood as combination of tangible and intangible aspects of the site. The final conservation plan will involve input from all stakeholders: conservation is not a top-down approach any longer. Accurate understanding of threats

¹¹ David Throsby, "Cultural Capital and Sustainability Concepts in the Economics of Cultural Heritage," *Assessing the Values of Cultural Heritage*, Marta de la Torre, ed., (Getty Conservation Institute: Los Angeles, 2002), page 104.

¹² *Ibid*, page 104.

to a site can lead to informed conservation treatment priorities that will ultimately achieve the goals outlined in a preservation plan. Two methodologies readily adapted to heritage conservation from related fields can help determine an appropriate treatment compromise: risk management and conservation triage.

Risk Management and Conservation Triage

Recent trends in heritage conservation focus on notions of risk, danger, and threat as a means to draw attention – and funding – to monuments and sites, which are not renewable resources as defined for some natural resources. In response to these threats, UNESCO declared the entire decade of the 1990s the “Decade for Natural Hazard Reduction.”¹³ The World Monument Fund (WMF) publishes an inventory of threatened resources in its “100 Most Endangered Sites” as a means to direct “timely financial support to their protection,” and UNESCO compiles its own “List of World Heritage in Danger.” In 1999, the General Assembly of ICOMOS, a sub-group of UNESCO, endorsed the Heritage@Risk program, an initiative charged to identify threats, to propose solutions and preventive measures, and to explore case studies of sites considered by conservators and stewards “at risk.”¹⁴ Conferences with titles such as *Management of disaster mitigation and response programs for historic sites: a dialogue* explore techniques in handling earthquakes, floods, cyclones, neglect, vandalism, and

¹³ Dirk H.R. Spennemann and David W. Look, *Disaster Management Programs for Historic Sites*, (National Park Service et al: San Francisco, 1998), page iv.

¹⁴ ICOMOS World Report 2000 on Monuments and Sites in Danger, “Trends, Threats and Risks,” http://www.international.icomos.org/risk/trends_eng.htm, January 21, 2003.

weathering.¹⁵ As these initiatives indicate, identifying and planning for risk serves as a technique for conservators to focus priority on selected sites. This move toward “preventive conservation” represents a shift in thinking from the trend of intervention as a remedial treatment.

“Risk” is anything that jeopardizes the longevity of a site or monument. Mechanisms of material decay can serve as indicators of risk, and treatment decisions and policy protection can increase or decrease levels of risk. According to the first report of Heritage@Risk, “In many ways, the real type and level of risks affecting a heritage place, a monument or site is indicative of its total effective level of protection.”¹⁶ Risk, therefore, can be caused by natural disasters, material deterioration, social factors, or by ineffective resource management. Reading current condition for sources of potential risk represents an emerging component of the documentation and assessment process in conservation planning. If conservators read existing condition patterns as indicators of risk, preventive treatment becomes more accurate and effective.

“Risk” as a management principle is employed regularly to prioritize treatment and funding programs in related fields such as environmental management. “Biodiversity hotspots,” a term used in environmental conservation, are similar in concept to lists such

¹⁵ Spennemann and Look, page 73.

¹⁶ ICOMOS, World Report 2000 on Monuments and Sites in Danger, “Effective Protection Against Risks,” http://www.international.icomos.org/risk/trends_eng.htm, January 21, 2003.

as the “100 Most Endangered Sites” by the WMF: “[Hotspots are] where exceptional concentrations of endemic species are undergoing exceptional loss of habitat... This opens the way for conservation planners, focusing on these hotspots in proportion to their share of the world’s species at risk.”¹⁷ Just as environmental managers face growing needs and pressures on existing resources, so do cultural resource managers. More and more sites are officially listed and recognized as integral – or valuable – to national or international heritage. Priority Treatment Schedules that identify urgency based on value and risk are critical as “conservation faces growing needs and diminishing resources. In the future, economic constraints will deny conservators the luxury of believing that every object or monument be afforded the same high level of attention.”¹⁸

Stewards of cultural resources must address risk in three primary areas: threats to the physical fabric of the site, threats due to management parameters, such as budget constraints, legislation, and available technology, and threatened cultural significance or social value inherent in the site.¹⁹ A central concern is to identify ways that conservators, trained in interpreting material deterioration through current condition, can become better risk managers by reading existing condition as indicators of risk. This thesis will explore

¹⁷ Norman Meyers, “Threatened Biotas: Hotspots in Tropical Forests,” *Environmentalist*, Volume 8, Number 3 (1988), page 4.

¹⁸ Jeffrey Levin, “The Future of Conservation,” *Conservation*, (Getty Conservation Institute: Los Angeles, 1991), Volume 6, Number 1, Fall 1991.
http://www.getty.edu/conservation/resources/newsletter/6_1_future.html, October 17, 2002.

¹⁹ Erica Avrami, Randall Mason, Marta de la Torre, *Values and Heritage Conservation*, (Getty Conservation Institute: Los Angeles, 2000), page 4.

one way to use digital technology and data display to better understand condition patterns as potential sources of risk to cultural resources.

Condition Assessments and Documentation

Fundamental to conservation planning is an understanding of the physical and social factors relevant to the site. Condition assessment and site recordation provide one format by which to investigate the history of use, influence of landscape, construction sequence, and physical properties of a heritage site. Assessing current condition should form the first tier of any conservation plan. Initial documentation steps – site sketches, physical investigations, interviews, and photographs – are critical, particularly as the field of heritage conservation broadens in scope. Site documentation establishes baseline data necessary for a multidisciplinary approach to conservation treatment and site interpretation. Recent projects of the University of Pennsylvania’s Architectural Conservation Laboratory have shown that digital tools can enhance site analysis, as well as facilitate graphic aids for project presentation, funding applications, and public awareness.²⁰

Documentation for conservation has long focused on recording the condition of a site before and after treatment, as a method to assess the success – or failure – of treatment and to measure the physical changes caused by treatment processes. Condition

²⁰ Frank Matero and Judy Peters, “Toward the Development of a Methodology for the Conservation of Historic Burial Grounds and Cemeteries,” Unpublished Draft for *Journal of the Association of Preservation Technology*, October, 2002, page 1.

assessments have also emerged, however, as a means to better understand mechanisms of deterioration and decay. An eight year, phased conservation project recently completed by the Architectural Conservation Laboratory of the University of Pennsylvania explored survey and analysis, as well as masonry stabilization and site interpretation techniques, at Mesa Verde National Park, Colorado. Graphic condition display served as a major focus of the project. Condition assessments were utilized not only as a measure of treatment success or failure, but also as a tool to better understand the complete nature of the site – the impact of past change, material design, use, and environment: “It has also been through the study of existing condition as a record of past change that conservators have seen the value of documentation and recording in developing a more accurate knowledge of alteration and deterioration. This is especially the case for understanding long-term trends and patterns of decay, as well as the efficacy of treatment performance and durability predictions.”²¹ The Mesa Verde Project highlighted the condition assessment as a primary tool in conservation planning. Although the scale used in condition assessment at Bandelier National Monument is not as fine, this thesis adopts a similar planning approach to that of the Mesa Verde project, and uses information gathered in the condition assessment to develop a more accurate knowledge of alteration and deterioration, especially as they are influenced by both physical and management factors.

²¹ Frank Matero, “Managing Change: The Role of Documentation and Condition Survey At Mesa Verde National Park, Colorado, USA,” *Journal of the American Institute for the Conservation of Historic and Artistic Works*, 2003.

While fundamental standards and protocols of site documentation remain those established by the Historic American Building Survey (HABS), advances in digital technology have produced new accurate and adaptable methods of generating condition data.²² Computer mapping programs provide a framework in which to store digital images, drawings tied to locations in real, cartographic space, and tabular data. A simplified explanation of GIS states, “In a GIS, you can study not just this map or that map, but every possible map. With the right data, you can see whatever you want – land, elevation, climate zones, forests, political boundaries, population density, per capita income, land use, energy consumption, mineral resources, and a thousand other things – in whatever part of the world interests you.”²³

The case study presented in this thesis will not attempt to study “every possible map,” but will focus on a very specific canyon within Bandelier National Monument in North Central New Mexico. Data collected in the summer of 2002 and stored in the GIS allows maps to be created based on layers of information, including physical dimensions of individual cave dwellings, aspect and orientation of cave clusters, as well as degree of plaster deterioration on cave walls, presence of structural cracking and geologic joints,

²² Site documentation, according to HABS Standards, are described in guidelines published by the National Park Service: “The drawing process typically begins with measuring each building by hand to produce field notes. Supplemented by 35mm field photography, these notes are used to construct the preliminary pencilings and produce ink-on-mylar drawings. Each generally includes elevations, plans, sections, details and a cover sheet with a site plan and written information...Recording tools also include photogrammetry, a means of extracting measurements from photographs.”

<http://www.cr.nps.gov/habshaer/habs/habscomp.htm> [2/3/2003 4:28:09 PM]

²³Tim Ormsby et al, *Getting to Know ArcGIS Desktop*, (ESRI Press: Redlands, California, 2001) page 1.

and density of culturally significant archaeological features extant in cave dwellings. This thesis will use a condition assessment for a group of significant cliff dwellings at Bandelier National Monument in order to investigate the recorded landscape context of each structure, and compare the context to existing symptoms of risk, such as structural cracking or rock disintegration. Thesis field work and analysis relied heavily on digital tools such as relational databases, vector drawing programs, digital photography, and Geographic Positioning System (GPS) data, combined in a Geographic Information System (GIS), in order to better understand factors that put cliff dwellings at Bandelier National Monument at risk.

**GEOGRAPHIC INFORMATION SYSTEMS
AND CULTURAL RESOURCE MANAGEMENT**

In his introduction to the published report of the Bandelier Archaeological Survey, conducted over six years from 1987 – 1991, Robert Powers credits intellectual curiosity as the impetus for site surveys. However, it was the National Historic Preservation Act of 1966 (amended in 1980) that provided a legislative mandate for full inventory of cultural resources within any National Monument. In order to comply with Section 106 of the Act, which requires federal agencies to consider the effect of any federal project on historic resources, the historic asset must be surveyed and identified. Researchers and managers alike have used Section 106 compliance requirements as an opportunity to collect enormous amounts of data that relate to archaeological sites and structures. As Powers notes, “Although there will always be a variety of opinions as to how the National Park Service should best conserve cultural resources for future enjoyment, there is usually agreement that decisions must be based on data gathered from the resource

itself, and that these archaeological data should satisfy both management and research requirements.”²⁴

Surveys that locate and catalogue resources create data that are useful to multiple research interests; stakeholders use the data to satisfy individual study interests. Maps have long been used as the common medium to which data from different sources can be tied and referenced. This chapter describes ways in which maps can be used for site analysis, site planning, and presentation. I will describe the components that make up a GIS, as well as consider its application as a tool for cultural resource management.

Map Analysis, Thematic Layers, and the Development of GIS

Maps and thematic map overlays are used as a way to break down large amounts of data into manageable layers of information. “Thematic maps,” defined as “maps in which colors or other symbols are applied to features to indicate their attributes,” are fundamental to a GIS.²⁵ Thematic data are “features of one type that are generally placed together in a single geographical layer.”²⁶ Points, lines, polygons, or raster pixels may be used to represent tangible features such as extant ruins, trails, vegetation, or intangible factors such as management priorities, proximity, and density. All of these features may be considered thematic data. Today thematic map layers are generated digitally in a GIS,

²⁴ Robert P. Powers and Janet D. Orcutt, eds, *The Bandelier Archaeological Survey: Volume 1*, (National Park Service, Intermountain Cultural Resource Management: Santa Fe, New Mexico, 1999), page 5.

²⁵ Tim Ormsby et al, *Getting to Know ArcGIS Desktop*, (ESRI Press: Redlands, California, 2001) page 7.

²⁶ Anne Kelly Knowles, “Glossary of Terms,” *Past Time, Past Place: GIS for History*, (ESRI Press: Redlands, California, 2002), page 191.

although as early as the nineteen sixties, landscape architect Ian McHarg used manual layering techniques to pioneer the use of thematic map layers for land-use planning.

A summary of McHarg's map layering approach illustrates the applicability of map analysis to cultural resource management. McHarg regarded individual land-uses as thematic layers. In addition, he considered site values, such as historic, social, and environmental values, as a set of evolving processes. These values were understood as dynamic and changing. Each value, identified in a process similar to the method of writing of a statement of significance, described in Chapter 1, is represented as a series of polygons on a single layer. Layers can be separated or visually combined in order to understand the "intrinsic suitability for certain land uses."²⁷ In this manner, through the use of graphic shading and hatching, areas of historic significance can be overlaid by land-uses such as commercial zones or areas of environmental integrity in order to understand the facets of a single site. In a 1969 study that considered suitable land-use possibilities for Staten Island, New York, McHarg created a series of layers on transparent sheets of mylar, and combined layers in much the same way that a GIS digitally combines maps on a computer screen.²⁸

²⁷ Ian McHarg, *Design With Nature*, (Natural History Press: Garden City, New York, 1969) page 104.

²⁸ *Ibid.*, pages 105-110. Broad data categories relevant to Staten Island, such as climate, historical geology, surficial geology, physiography, hydrology, soils, plant ecology, and wildlife habitats, were mapped. Each map was interpreted, so that within each category a number of factors were selected, evaluated, and ranked. For example, on the "geology" map, specific features were shaded to represent various values, such as scientific, educational, and geologic values. Each feature was then assigned a grade that ranged from "unique" to "abundant." Finally, each feature was evaluated based on physical condition or properties, such as the relative compressive strength of rocks. Once this process was performed for each of the broad



Figure 3.1 *States, rivers, and lakes are each a distinct thematic layer, digitally combined.*

This approach serves as a useful means to distill complex information through the use of graphic design, as emphasized by Edward Tufte in his book *Envisioning Information*: “Among the most powerful devices for reducing noise and enriching the content of displays is the technique of layering and separation, visually stratifying various aspects of the data.”²⁹ McHarg’s method of layering transparent thematic maps represents a graphic approach to methodical site planning. As McHarg explained, “In addition to being

categories, the prospective land-uses were considered. For each prospective land use, features have more or less impact or importance; eventually, a hierarchy of features emerged for each prospective land-use.

²⁹ Edward R. Tufte, *Envisioning Information*, (Graphics Press: Cheshire, Connecticut, 1990) page 53.

rational, the method is explicit. Any other person, accepting the method and evidence, is likely to reach the same conclusion as those demonstrated in the study... moreover, this method permits a most important improvement in planning method – that is, that the community can employ its own value system.”³⁰ This is particularly relevant to the field of cultural resource management, which struggles to incorporate multiple notions of value into the preservation planning process. Once a conservator has identified site values, thematic layers offer a tool with which these values may be displayed and understood in context and in relation to one another.

In their article, “Computer Maps for Cultural Resource Planning,” John Knoerl and Sandy Weber appreciate the results of map analysis, yet highlight predictable drawbacks of using multiple transparent paper maps; Knoerl and Weber instead advocate computer mapping with GIS: “[Paper maps] often contain so much information that little sense can be made of them, and most do not contain the kind of data needed to solve complex issues such as viewshed problems or trail-siting alternatives. Paper maps are also costly to produce and revise, severely limiting available options and analysis opportunities.”³¹ By the mid 1970’s, the United States Geographic Survey (USGS) had participated in the development of computer software to handle cartographic data. Prior to 1960, the USGS

³⁰ McHarg, page 105.

³¹ John Knoerl and Sandy Weber, “Computer Maps for Cultural Resource Planning,” *CRM*, Volume 11, Number 4, August, 1988, page 11.

relied entirely on manual cartographic techniques such as those described by McHarg: drafting and transparencies were combined with photography to perform analysis.

As computer programs automated cartographic tasks, two branches of computer mapping developed within USGS. One branch focused on automating production of traditional map graphics. The second branch sought to develop digital data as a distinct product, to be used as information that can be analyzed, combined with other data sets, and used to produce a new body of information.³² In simpler terms, a GIS has the power to produce maps that mimic traditional paper maps, but can also be used to generate new sets of spatial data.

Although the debate of how to best use GIS within the Department of the Interior continues today, the National Park Service has adopted the technology for use as a planning and management tool. The NPS has invested time and money in training, database development, and technical support for GIS systems, and has established GIS programs on three levels: national initiatives, regional support offices, and park-based systems.³³

³² David Greenlee and Stephen C. Guptill, "GIS Development in the Department of the Interior," *The History of Geographic Information Systems: Perspectives from the Pioneers*, (Prentice Hall PTR: Upper Saddle River, NJ, 1998) page 182.

³³ National Park Service website, <http://www.nps.gov/gis/description.html> (February 21, 2003).

Components and Capabilities of a GIS

GIS is a computer system based on databases of information that include a spatial reference for each record. There are several software programs available to process and display data stored in a GIS; this thesis relies on two versions of GIS software produced by Environmental Systems Research Institute (ESRI), ArcView 3.2® and ArcGIS 8.1®.

A GIS combines graphic computer mapping abilities, available through vector-based drawing programs such as AutoDesk® AutoCAD® or Adobe Illustrator®, with a database management system similar to Oracle® or Microsoft Access®.³⁴ Drawing programs afford capabilities such as the ability to draw and move features and to change shading and line width.³⁵ Database programs provide a means of calculating, sorting, and querying records stored in a table. Data stored in a GIS table is represented as a series of fields and records, similar to a spreadsheet, with an additional component: each record includes a field in which the spatial location for every feature is recorded as a pair of geographic coordinates. Thus, the attribute table records information about the components that make up an object or feature, as well as where the object is located.³⁶ This combination of functions provides the capability to visualize data on a computer screen as McHarg did with acetate transparencies, as well to assign numeric values or text attributes to each feature represented on the map. New fields may be added to the

³⁴ Ian Gregory, *A Place in History*, <http://hds.essex.ac.uk/g2gp/gis/sect12.asp> (March 19, 2003).

³⁵ Ian Gregory, *A Place in History*, <http://hds.essex.ac.uk/g2gp/gis/sect12.asp> (March 19, 2003).

³⁶ Ian Gregory, *A Place in History*, <http://hds.essex.ac.uk/g2gp/gis/sect12.asp> (March 19, 2003).

data table at any time by users with access to the database. In addition, a spatially referenced database creates a framework into which data from different sources and disciplines, such as wildlife management and cultural resource management, can be combined based on a common geographic coordinate.

A GIS requires three components: data, a data processor – a computer – and a mechanism for display. Three categories of data can be processed and combined by a GIS: tabular databases, raster-encoded digital images, or vector-based digital drawings. These three groups of data correspond with data collected and generated in site documentation work, such as a database in which condition information is stored, photographs of the site, and field sketches and architectural elevations and site plans. Archaeologists, visitors, conservators, and managers have been documenting resources at Bandelier National Monument for over a century. Archives at Bandelier contain site plans of pueblo ruins, photographs of conservation treatment campaigns, narrative accounts of visits, and field data forms from field condition surveys. Each of these components can be integrated in a GIS. Once the data are stored in a digital format, the processing capabilities of a GIS include data presentation, data interpretation, data preparation, and programming.³⁷

³⁷ Dana Tomlin, Course Materials for Modeling Geographic Space, Spring Semester, 2003, "ArcGIS01: Introduction," page 2.

Data presentation allows a user to control the graphic manner in which information is presented, and data interpretation allows stored data to be used to generate new information that “explicitly convey[s] information that would otherwise remain only implicit.”³⁸ These two capabilities of a GIS are fundamental tools for cultural resource managers. Data, presented in digital layers, may be displayed in order to highlight features of a site for visitors, to explore areas of risk or concern at several scales, and images, text, and graphics may be combined to describe a landscape. Data may also be queried, based on spatial characteristics or attribute information. Queries and calculations from existing data may be stored as new data. For example, a query may be written to display all visitor trails located within one hundred feet of a pueblo ruin; the trails could then be represented with line weights that represent width, type of paving, or current condition. Results of queries may be stored as new lines with all of their associated attributes, and may be inserted in to future maps.

Queries may be based on the location of a feature within a map, or on the attributes stored in the data table of a feature. A more refined application of the geographic information stored in a GIS uses features from one layer to select or features on another layer; in addition, information contained in one attribute table may be jointed to that of another based on location. This allows users to establish links between and among features based on spatial relationships, and serves as a step to making explicit a relationship that may

³⁸ Tomlin, “ArcGIS01: Introduction,” page 3.

otherwise remain implicit – or even hidden – in the data. Language used in the selection and spatial joining methods clarifies relationships that can be explored: features that “contain”, that “are completely within,” that “intersect with,” or that “share a line segment with” other specified features may be selected. Spatial joins may be based on relationships such as proximity to, distance from, or intersection of specified features.³⁹ This process is continual: as new relationships are understood, new data is produced from which new maps can be created. As Matero, Hinchman, Tomlin, et al. state in their article “What is Past is Prologue: GIS-Based Condition Assessment of The Great Hall Ceiling at Drayton Hall, South Carolina,” “[GIS] is not intended to produce a single end result but instead to provide, through different mathematical analysis, a set of comprehensive data and images that can introduce previously unavailable information.”⁴⁰

Data preparation capabilities of a GIS facilitate combining data that exists in various formats, digital and non-digital, from different sources into a common framework.⁴¹ Historic or contemporary paper maps may be scanned, digitized and referenced for use in a GIS, and data acquired from Global Positioning (GPS) Units may be converted into a file-type used by the GIS (the GIS work for this thesis primarily used shapefiles, the file-type associated with ESRI vector analysis. Some grids, or raster images, were also

³⁹ Dana Tomlin, Course Materials for Modeling Geographic Space, Spring Semester, 2003, “ArcGIS18: Spatial Joins,” pages 4-6.

⁴⁰ Frank Matero, John Hinchman, Dana Tomlin, and Kyu-Bong Song, “What is Past is Prologue: GIS-Based Condition Assessment of The Great Hall Ceiling at Drayton Hall, South Carolina,” Unpublished Draft for the *Journal of the Association of Preservation Technology*, October, 2002, page 10.

⁴¹ Tomlin, “ArcGIS01: Introduction,” page 3.

imported into the system). Data may also be edited for use in the GIS. The data preparation capabilities of a GIS allow the system to act as a framework or a repository for data and resources. There exists a degree of flexibility in the kinds of data incorporated into a GIS, which facilitates a multidisciplinary approach to conservation planning. In this thesis, for example, site plans, elevation drawings, and photographs, as well as existing digital contour lines and trail data compiled by wildlife resource managers were combined with field survey data in order to present information at several levels of detail and scale.

Just as paper maps are a two-dimensional representation of the spherical world, so is a map produced in a GIS. Flattening the three-dimensional world onto a paper or a computer screen creates spatial inaccuracies. The process of conversion from a three-dimensional sphere (such as a globe) to a two-dimensional, flat representation of the sphere is known as projecting into a planar coordinate system. A variety of planar coordinate systems exist for projection. Each different system begins from a specific point, known as a datum, and displays all data in relation to that datum point. A datum is defined as the mathematical understanding of where the center of the earth is located; therefore, depending on the cartographer's choice of a datum, features are displayed differently.⁴² Thus, if a GIS is used to map real points in space, the datum point from

⁴² Tomlin, "ArcGIS16: Coordinate Systems," page 1.

which locational coordinates for each feature are derived will influence how the representation will appear.

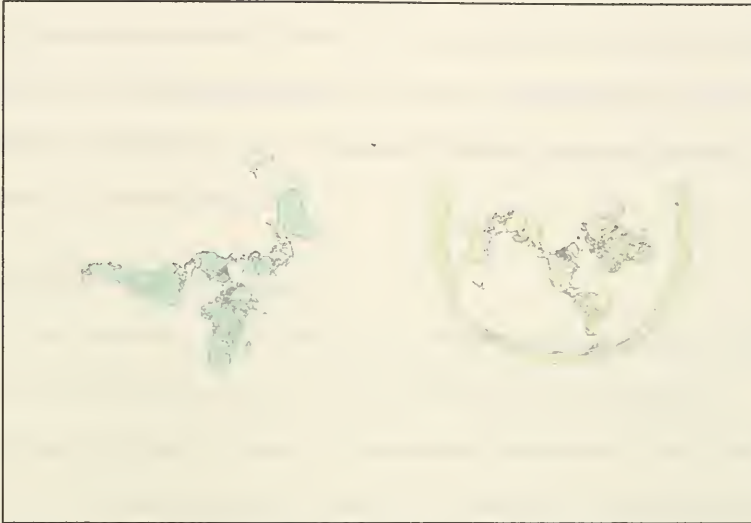


Figure 3.2 *The projection of the left, called “North American Equidistant Conic,” presents the same world data as the projection on the right, called the “Canada Lambert Conformal” projection.*

Conservation planning for a heritage site as extensive as is Bandelier National Monument (32,737 acres) requires an examination of resources at multiple levels of detail and scale. Landscape, history of use and occupation, as well as physical condition of individual features are integral to site preservation. must be considered both together and as individual components. One application of a GIS is to combine data from different sources and to investigate a site at multiple scales in order to work with a variety of “resolutions.” or levels of detail. Combining data at fine and course scales is only

possible if all of data assumes the same projection and point of reference. If two different projections are used, feature layers will appear skewed or mismatched if they are not derived from the same datum. A goal of this thesis is to create a spatial framework for use in cultural resource planning at Bandelier National Monument; in order that location data collected in the field can be combined with existing geographic data, this project assumed the standard datum used for all projects at Bandelier, the North American Datum of 1927, known as NAD 27.⁴³

GIS at Bandelier National Monument

GIS as a data framework, to which data can be continually added and updated, is a useful tool for cultural resource managers. GIS can facilitate the objective articulated by Randall Mason, discussed in Chapter 1, for conservation professionals to “cast a wider net” and to incorporate data originally collected for related fields in a conservation plan in order to develop a more inclusive – and thorough – preservation strategy. In the case study presented in this thesis, GIS is used to examine conditions among a group of approximately one hundred sixty six cliff dwellings. The data represent information at a mid level of detail; additional research can be conducted to understand the impact of the larger landscape (including hydraulic drainage patterns and geologic shifts) on overall condition and distribution of structures. In addition, condition research conducted at a

⁴³ The North American Datum of 1927 (NAD 27) is an arbitrary datum point established by cartographers in 1927. Many maps use NAD 27 as a standard point from which to calculate cartographic data, although newer datum points may soon become the standard. At this time, geographic data collected at Bandelier uses NAD 27 as the point which represents the center of the earth.

finer scale of a single cliff-dwelling can provide greater insight as to ways in which symptoms of deterioration permeate the rock substrate. Field data incorporated in to the framework of this thesis can be used as the basis for future research at different scales.

Bandelier National Monument, located in northern New Mexico, provides a challenging case study in the application of GIS to Cultural Resource Management. The landscape includes high, flat mesas as well as seven canyons. Elevation can change quickly within a small area. The climate of northern New Mexico includes large temperature shifts, and wind, water, snow and sun act as agents of material deterioration. Bandelier is valued for two distinct resources: the wide swath of wildlife habitat it provides, as well as the architectural and archaeological features that provide insight into settlement patterns of the Native American Pueblo tribes of the Southwest. In addition, stakeholders such as ecologists, tourists, archaeologists, and descendants of the original Pueblo inhabitants of the site assign value and significance to the site.

A GIS that uses ESRI's ArcView 3.2® software is in place for wildlife management at Bandelier. The GIS is used to monitor the effects of forest fires on native and introduced plant species, elk and prairie dog populations, and the relationship between the increased deer population and a declining Aspen tree population. Wildlife technicians have long relied on geographic data collected in the field, and have managed data and utilized cartographic models in both predictive and descriptive capacities. Cultural resource

managers, however, have relied more heavily on periodic resource condition assessments – entered by hand in the field on to tabular data forms – as a means to monitor change in existing architectural features.

The National Park Service has experimented with the use of GIS as a tool for Cultural Resource Managers, and has established the Cultural Resources Mapping and GIS group to disseminate papers, reports, and training opportunities.⁴⁴ Most of the efforts by the NPS thus far have focused on GIS as a means to organize and display data. In a paper presented at the 10th Conference on Research and Resource Management on Public Lands, Deirdre McCarthy and James Stein assert that, “Collecting the locational data with GPS as well as basic attribute information associated with individual features, and combining that with the power of GIS to integrate different data sources, allows preservationists to take advantage of these technologies in planning and researching cultural resources.”⁴⁵ Data display is a useful means of understanding the complicated landscape of Bandelier National Monument; however, display is only one way to use GIS at Bandelier. The data interpretation capabilities of a GIS can help illustrate the relationship between the context of each structure within the greater landscape and symptoms of risk that lead to deterioration. Symptoms, such as disintegration and detachment, can be treated by conservators. With a greater understanding of locations

⁴⁴ The Cultural Resources Mapping and GIS website is located at <http://www2.cr.nps.gov/gis/index.htm>.

⁴⁵ Deirdre McCarthy and James Stein, “Applying GIS and GPS to Historic Preservation and Architectural Surveys,” Report presented at the 10th Conference on Research and Resource Management on Public Lands, National Park Service, October, 2002.

and conditions that indicate risk, interventions can be planned and prioritized according to a range of factors including condition, significance, access, and potential threat.

FRIJOLES CANYON CASE STUDY

In this chapter, I will establish the significance of Frijoles Canyon, and offer contextual information about the study area by describing the location and outlining the legislative history of the region. In addition, I will provide a description of the primary structures in the site based on historical accounts and geologic development. This thesis focuses on a select group of cavates known as Cavate Group M, and I will include a discussion of why I chose to use Group M as the test area in which to apply GIS technology. I will detail the data collection methods used in the summer of 2002 in order to create the framework and basic feature data for the GIS. Lastly, I will present the condition assessment of Group M cavates, which was conducted by the summer field school in 2002.

Site Significance

Although physical evidence indicates that the region within the boundaries of Bandelier National Monument has been occupied by humans for more than 10,000 years, it was ethnographer and explorer Adolph Bandelier who provided the first written description of

the archaeological ruins in 1880. What so captivated Bandelier in his first of several expeditions through Frijoles Canyon was evidence of human occupation such as cliff dwellings, masonry pueblos, shrines, and trails.⁴⁶

The cliff dwellings of Bandelier National Monument are architecturally significant due to their unique construction in the rock walls of Frijoles Canyon. In addition, they are culturally significant as a record of Native American settlement patterns in the region.

The importance of the site is comparable to other sites recognized internationally as

World Heritage Sites:

The caves in Bandelier are one of the largest concentrations of troglodytic structures in North America, and are comparable to other settlements hewn into rock in Cappadocia in Turkey, Matera in Italy, and Matmata in Tunisia. The modification and use of the natural geology for habitation, the density of sites, and the relationship between these small, carved residential chambers and the large, stone masonry civic structures in the surrounding landscape, is extraordinary.⁴⁷

Despite recognition of the site's significance through protective legislation, the cliff dwellings are still considered at risk due to natural environmental factors such as erosion, aging, and damage incurred by water and wind. Human activity, such as tourism, also represents a risk to the fragile structures excavated out of soft volcanic material. In 2001 the site was listed as one of the 10 Most Endangered Sites in New Mexico; the

⁴⁶ Robert P. Powers and Tineke Van Zandt, "An Introduction to Bandelier," *The Bandelier Archaeological Survey: Volume I*, Robert P. Powers and Janet D. Orcutt, eds. (National Park Service, Intermountain Cultural Resources Management, Anthropology Program: Santa Fe, New Mexico, 1999), page 2.

⁴⁷ Angelyn Bass Rivera, "World Monuments Watch 2004 Nomination Form," (January, 2003) page 3.

management principle of risk, discussed in Chapter 1, has been incorporated into efforts to raise community awareness of the Bandelier cliff dwellings.

Location

Bandelier National Monument lies in the center of the Pajarito Plateau, in the Northern Rio Grande Valley of Northern New Mexico. The wide mesa of the Pajarito Plateau slopes to the southeast, and is bounded on the west by the Jemez Mountains, on the east by the Rio Grande, on the north by the Rio Chama Valley, and on the south by the Canada de Cochiti.⁴⁸ Elevations in the region vary widely – from 5,300 feet to 10,200 feet. The monument, federally managed by the National Park Service, now encompasses fifty-one square miles of wilderness area and ancestral pueblo cultural remains. Seven major canyons, located within the Monument boundaries, drain the Pajarito Plateau; predictably, rivers and streams in the area tend to flow southeast toward the Rio Grande. Through one of these canyons, known today as Frijoles Canyon, runs the small Rito de los Frijoles. For 2.5 miles the river flows through the canyon to empty downstream in the larger Rio Grande River. The Rito de los Frijoles cuts through a thick blanket of volcanic rock as tuff, which was deposited on the Pajarito Plateau by two major volcanic eruptions, each over 1 million years ago.

⁴⁸ Robert Powers and Tineke Van Sandt, “An Introduction to Bandelier,” *Bandelier Archaeological Survey: Volume I*, Robert Powers and Janet D. Orcutt, eds (National Park Service, Intermountain Cultural Resource Management: Santa Fe, New Mexico, 1999), page 6.

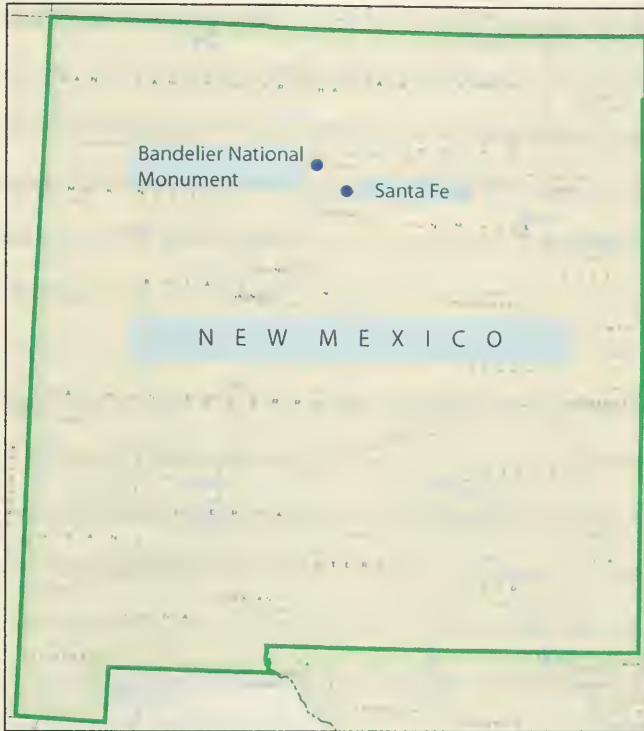


Figure 4.1 State map of New Mexico, based on <http://www.nps.gov/band>.

Management and Legislation

Multiple groups and government agencies have struggled for control of the natural and archaeological resources of the Pajarito Plateau. The year-round presence of water in Frijoles Canyon made it a center for waves of human settlement for millennia. Available water, plentiful vegetation, and the high concentration of pueblo ruins have left Frijoles Canyon particularly vulnerable to competing interests in the last one hundred fifty years. Environmental studies indicate that beginning in the mid nineteenth century, for example,

ranchers used Frijoles Canyon for extensive grazing of sheep and goats. By the late nineteenth century, archaeologists had “discovered” pueblo ruins in the area. Native Americans of the surrounding Pueblo tribes, archaeologists, homesteaders, ranchers, real estate developers, and different federal agencies have struggled for control of existing resources, and early efforts to designate the region a National Park were thwarted as each group fought to legally manage the area.⁴⁹

Bandelier’s published accounts of his time in the region drew attention to archaeological resources of the Pajarito Plateau. By the end of the nineteenth century, as more Americans explored the Southwest in general and the New Mexico Territory in particular, the Pajarito Plateau became accessible, and susceptible, to archaeologists. In 1900, the Smithsonian expressed an interest in preserving, for educational and scientific purposes, the extensive group of cliff dwellings in Frijoles Canyon; in April of 1900, the newspaper *The New Mexican* cautioned that the area was in danger of “deadly relic hunting.”⁵⁰

By the turn of the twentieth century, Edgar L. Hewett, one of the earliest archaeologists to attempt systematic surveys and studies in the area described by Adolph Bandelier, was well aware that the cultural sites of the increasingly crowded Southwest were in danger.

⁴⁹ Hal Rothman, *Bandelier National Monument: An Administrative History*, (National Park Service, Division of History, Southwest Cultural Resources Center: Santa Fe, New Mexico, 1988), page 9.

⁵⁰ Thomas L. Altherr, “The Pajarito or Cliff Dwellers’ National Park Proposal, 1900-1920,” *New Mexico Historical Review*, July, 1985, page 276.

He lobbied forcefully for federal protection of the cave dwellings and pueblos of Frijoles Canyon. In response to growing tensions and differing goals among excavators and explorers, the federal General Land Office (GLO) began, in the 1890's, to reserve parcels of land from claims until the area could be studied to determine appropriate land use. Although Hewett never succeeded in persuading Congress to declare the area a National Park, he was instrumental in drafting the Antiquities Act of 1906.⁵¹ In June of 1906, Congress approved the Antiquities Act, which allowed the President to designate areas "of historic or scientific interest" as national monuments, to be managed by the United States Department of the Interior.⁵² In 1916 President Woodrow Wilson exercised the power granted the Executive Branch by the Antiquities Act and designated a swath of land that included Frijoles Canyon a National Historic Monument. The 18,000 acre area on the Pajarito Plateau was offered Monument status in the same year that the National Park Service was created, although it was the National Forest Service that managed the Monument until 1932.

Cavate Structures

Of primary interest and significance to archaeologists at the turn of the twentieth century was the concentration of ancestral Puebloan ruins in the region. In a 1904 article published in *The American Anthropologist*, Hewett described his survey and excavation work on the Pajarito Plateau, and noted that the variety of architectural remains provided

⁵¹ Lauren Meyer, "Frijoles Canyon, the Preservation of a Resources," University of Pennsylvania Masters Thesis, (May, 2002) page 51.

⁵² Antiquities Act of 1906, Section 2.

insight into a range of pueblo settlements: "It was believed that Pajarito Park, extending from Santa Clara canyon on the north to Rito de los Frijoles on the south, embraced practically every phase of the prehistoric culture of the district."⁵³

Within Frijoles Canyon there are two primary categories of ruins: pueblo ruins and cliff-dwellings. Hewett defines pueblo ruins as "communal houses of the Pueblo Indians that



are situated on mesas, in valleys, or on plains, independent of support from natural rock walls; they are both ancient and

Figure 4.2 *Tyuoni Pueblo: a circular, communal pueblo in Frijoles Canyon.*

modern, and are always multiple-chambered."⁵⁴ Rainbow House and Tyuoni Pueblo are two large, circular pueblo ruins located near the Rito de los Frijoles in Frijoles Canyon.

⁵³ Edgar L. Hewett, "Archaeology of the Pajarito Park," *American Anthropologist*, Volume 6, 1904, page 632.

⁵⁴ *Ibid.*, page 634.

In addition to communal pueblo ruins, there are over 1,000 cliff dwellings, known as cavates, in the rock walls of Frijoles Canyon. Hewett, again in 1904, draws a distinction between the general term “cliff dwellings” and the more specific term “cavates.” Cliff dwellings are “ancient dwellings of sedentary Indians that are wholly or in part embraced within cliffs, built against cliffs, or situated on ledges under overhanging cliffs,” and within this type are the more narrowly defined “cavates,” which are “usually but not always single-chambered; not in strongly defensive sites; originally shaped by wind erosion but enlarged and further shaped by excavation, which was the only industrial process employed in their construction.”⁵⁵ All of the cavates assessed in the case study for this thesis were formed in the manner described by Hewett, and many of the dwellings were augmented with added masonry walls that supported appended roofs and constructed rooms.⁵⁶

There are over 1,000 ancestral pueblo cavates located in Frijoles Canyon, which represent a distinct physical record of Pueblo culture before European settlement of the Rio Grande region. By the time of Bandelier’s arrival in the Canyon, the dwellings had long since been abandoned; archaeologists have determined that the primary period of occupation was from AD 1150-1600.

⁵⁵ Ibid., pages 633-636.

⁵⁶ As specific as Hewett’s definition of “cavate” is, Toll notes that there is variability among cavates. In his 1995 study *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument*, Toll summarizes the various definitions of “cavate” used in the twentieth century and concludes, “Both Mindeleff and Hewett recognized that there is variability in these features, how they are incorporated into structures, and how they relate to other sites lacking cavates.” (Toll, page 1).

Cavate structures are not unique. As noted above, the cavates located within Bandelier National Monument are similar in construction technique and appearance to sites such as Cappadocia in Turkey, Matera in Italy, and several sites in Tunisia. In the United States there are only four areas of the American Southwest in which cavates are located: the lower San Juan River drainage, the Flagstaff region, the Verde Valley, and the Rio Grande area.⁵⁷

Geology

The density and distribution of cavates in Frijoles Canyon is due in large part to the geology of the Pajarito Plateau. Two volcanic explosions, the Valles and Toledo, erupted over one million years ago and dramatically impacted the regional landscape. The eruptions formed the Jemez Mountains and produced a volcanic ash, known as Bandelier Tuff, which settled over the Pajarito Plateau.⁵⁸ The resulting topography is one of wide, flat mesas separated by long and deep canyons. The soft Bandelier Tuff provides the material from which cavates are excavated, and in his 1991 study, H. Wolcott Toll illustrated that cavate distribution on the Pajarito Plateau coincides almost exactly with areas of Bandelier Tuff deposits.

⁵⁷ Toll, page 4.

⁵⁸ Powers, page 7.



Figure 4.3 Areas in pink show the distribution of Bandelier Tuff on the Pajarito Plateau, based on image by H. Wolcott Toll, page 4.

The stratigraphy of the Pajarito Plateau consists of a cover of volcanic ash that has hardened over layers of pumice and basalt. Two categories of Bandelier Tuff – Tschirege Member, or Upper Bandelier Tuff, and Otowi Member, or Lower Bandelier Tuff – cover the Pajarito Plateau; each results from the volcanic activity of the region, and each is primarily a welded rhyolitic formation. In the report of the 1999 study *Tsankawi Unit Cavate Conditions Assessment and Treatment Recommendations* conducted by the Architectural Conservation Laboratory of University of Pennsylvania and the National

Park Service, Shaun Provencher highlighted the characteristics and differences of each variety of tuff. While Tschirege Member has been identified as the ash that forms the pink cliffs of Bandelier National Monument, its color is actually a somewhat muted gray. According to Provencher, “Otowí Tuff, found from the canyon floor to about halfway up the mesa [in the Tsankawi section of Bandelier National Monument] is of reddish color and is the significantly more friable of the two.”⁵⁹ Erosion caused by water flowing over the Pajarito Plateau sliced deep canyons in the tuff, which provided the material from which cavates were easily excavated by original inhabitants. The mechanical properties of Bandelier Tuff play a critical role in understanding the mechanisms of decay that erode cavate structures; the friability of tuff leaves cavates vulnerable to deterioration due to wind and water abrasion. All of the cavates included in the case study for this thesis are of Tschirege Tuff. Toll notes that the tuff found in Group M was particularly delicate: “Still, the tuff at Group M contains abundant soft, fibrous chunks of tephra, which probably leads to an increased rate of deterioration.”⁶⁰

Cavate Group M

During the field excavation seasons of 1908 and 1909, Hewett worked to clear, excavate, and document the cavates in Frijoles Canyon. He divided the 1,008 cavates along the north side of the canyon wall into thirteen groups, labeled A-M.

⁵⁹ Shaun Provencher, *Tsankawi Unit Cavate Conditions Assessment and Treatment Recommendations*, (National Park Service, Department of the Interior, Intermountain Support Office: Santa Fe, New Mexico), 1999, page 47.

⁶⁰ Toll, page 99.

H. Wolcott Toll describes how Hewett designated cavate groups:

Hewett and Chapman divided the cavates in Frijoles into Groups A through M based on breaks between clusters, which are often caused by drainages or stretches of cliff unsuitable for cavate construction. The separation between the groups they defined is only a few meters in several cases, and the groups vary considerably in size. Whether or not this long string of cavates was fourteen or more settlements, as implied by this topographic grouping, can only be inferred by careful study. Our recording is an early step in making this inference.⁶¹

The groups defined by Hewett nearly a century ago are loosely based on geologic features of the cliff face and may not reflect cultural settlement patterns, yet they remain a useful way to create study areas of a manageable size. Research and conservation projects still identify cavates by these thirteen groupings.⁶² (See Appendix C, Layout 1)

Group M was further subdivided into nineteen panels, designated with letters A-M, when the cavates were surveyed in 1991 as part of the Bandelier Archaeological Survey. These panels roughly conform to the contours of the cliff face. The panel divisions were maintained and used in field collection for this thesis.

Cavate Group M, located at the extreme down-river end of the cavate groups, serves as the study area for this thesis for several reasons. The group of one hundred sixty-six

⁶¹ Toll, page 16.

⁶² Toll, page 8.

cavates is located on a steep talus slope above the Monument's Visitor Center, and there are no maintained trails that lead to the site. Access to Group M is restricted; therefore, there are a high number of cavates that remain relatively undisturbed by tourist traffic. According to a recent report submitted by the Vanishing Treasures Program at Bandelier, fewer than one percent of the cavates in Frijoles Canyon have been modified through surface finishes treatment or structural conservation, and "most of the treatments have focused on stabilizing cavates that are open to the public, and reconstructing anterior masonry rooms and foundations to demonstrate to visitors the relationship of the cavates to masonry structures that once stood in front of them."⁶³ Most current maintenance and reconstruction projects run by the National Park Service occur in the few cavates open to the public in cavate groups A, B, C, and D. These factors – undisturbed cavates of original and unaltered material – make Group M an area of high integrity. Group M includes a variety of cavate sizes and shapes, such as a large, circular cavate, known as "Cave Kiva," that may have been a ceremonial space, as well as small and inter-connected cavate clusters. (See Appendix C, Layout 1)

Previous Studies in Cavate Group M

Previous studies carried out in Group M provide comparative information about the cavates through time. R.H. Lister conducted limited stabilization campaigns in Group M during the 1939 and 1940 field seasons, and extensive documentary and photographic

⁶³ Angelyn Bass Rivera, "World Monuments Watch 2004 Nomination Form," (January, 2003) page 5.

records exist of his project. Excavations conducted by J.W. Hendron in 1940 and 1943 provide a paper trail of information about the state of surface finishes in the cavates and structural stability in Group M during the seasons he spent in Group M.

H. Wolcott Toll recorded five cavate groups in his 1986-1991 study of Bandelier cavates, and in the published report of his findings he included tabular data that addressed cavate stability. Toll's stability ratings ranged from values one through four. Cavates assigned a stability value of one were considered stable, and in cavates with a value of two, deterioration was evident, though of a "lesser threat." Cavates with values of three and four showed greater threat, culminating in cavates considered a "major problem, [in which] collapse or major loss may be imminent."⁶⁴ In his description of cavate description, Toll notes that cavates in active deterioration can progress to stasis; cavates that have collapsed or deteriorated are considered "non-cavates," and generally remain stable. Toll writes:

On the whole, extremely fragile cavates are likely to have fallen apart long ago, becoming, for our purposes, non-cavates or non-existent.[...] Non-cavates tend to be more exposed and either have fewer features at risk (as with back walls) or have already experienced most of what loss was possible....Group M seemed to have the greatest deterioration problem. Of course, Group M has a large number of partial rooms, which accounts for its lower stability.⁶⁵

⁶⁴ Toll, page 227.

⁶⁵ Toll, pages 100-101.

Toll depended on photographs and documentation from previous documentation efforts in Group M, and noted that photographs taken by Lister were helpful to assess rates and degree of masonry deterioration.⁶⁶

Cavate Group M has long been a featured area of study due to its remote location, integrity of features, and distribution of cavate types. Comparative information can be incorporated into a GIS to compare assessments of risk and structural stability over two decades.

Data Collection and Field Work

In order to place cavate locations within the common framework of other projects at Bandelier, field work began by selecting the appropriate datum point and coordinate system to use as reference. As discussed in Chapter 2, employing the same cartographic base point for collecting information allows data from this project to be combined with spatial data associated with other projects at Bandelier, such as trail siting, studies of regional hydrology, and vegetation maps. All spatial data collected by managers at Bandelier is based on the North American Datum of 1927, established for the Continental United States (NAD 27, ConUS), set specifically for Bandelier's location based on the Universal Transverse Mercator (UTM) grid 13, North Section. The bulk of the geographic field data was collected in the summer of 2002.

⁶⁶ Toll, page 76.

The topography of the Frijoles Canyon site poses a number of challenges in collecting Geographic Positioning System (GPS) coordinates for each of the cavates. The narrowness of the canyon reduces the amount of sky visible from the vertical cliff face, which in turn reduces the number of receivable satellite signals available in the canyon. GPS receivers generally have a much higher horizontal accuracy than vertical accuracy; therefore, even when a GPS signal could be recorded, the elevation measurements logged had varying degrees of accuracy. With these limitations in mind, Lori Kleifgen of the Santa Fe Inter Mountain Support Office suggested that multiple forms of data, at different scales and levels of accuracy, be collected and assembled at once. In this process of examining the “convergence of evidence” as many GPS points as possible were collected in the initial phase of the project. Points were logged in random areas of the canyon, as well as points at known locations, such as the Frijoles Canyon Fire Tower. Logged GPS coordinates were then compared to the known elevation points in Frijoles Canyon in order to test accuracy of the GPS unit. In addition, the GPS location points were compared to other forms of cartographic and visual data, such as aerial photographs, trail maps, and existing hand drawn site plans. Any points that, when regarded in context were clearly in error, were discarded.

The Bandelier Park Cartographer, Kay Beeley, provided three aerial orthophotographs of Frijoles Canyon, taken in 1991, 1996, and 2000 by the Los Alamos National Laboratory.

Existing digital contour maps at two, ten, and one hundred feet intervals were overlaid on the orthophotographs. Based on the photographs, field observations, and contour lines, the general location of each cavate group was established. Cavate Group M was located on the aerial photos based on landscape features such as vegetation, rock falls, and visible natural dams. The aerial photographs provided useful boundary guidelines for early data collection. (See Appendix A, Figure A.2)

Data collection proceeded with a Trimble GeoExplorer3® GPS unit loaned by the Santa Fe Inter Mountain Support Office. Using digitized field maps produced by Mary Slater, known points were logged at the base of the talus slope of the canyon wall. The accuracy of the recorded locations was confirmed, which indicated that the Trimble GPS unit was a sufficient tool to use to log and store points. Recorded points were marked on the slope with a pin flag. The geometry of the satellite reception from within the canyon was such that it was increasingly difficult to record points as we proceeded up the talus slope. An early solution to this problem was to record points at low elevations that were in line with panel breaks within Group M, as identified on the digitized field maps. Once the point was logged and marked, we used a one hundred meter measuring tape and a digital compass to measure the distance and angle from the logged point to the cliff face. Based on these field measurements, the points could later be confirmed and located on a computer screen in the GIS. Once panels within Group M were recorded in the GIS based on field measurements, individual cavate locations could be estimated by establishing

them in relative positions to one another, within each panel. This estimation was not ideal.

By holding the GPS antenna ten feet above the ground, a far greater number of points were logged in the unit, including many points against the cliff face at the top of the talus slope. This improvement significantly increased the accuracy of points logged, and there was no longer the need to estimate the relative location of each cavate. Therefore, a magnetic plate was attached to a ten foot steel pole, provided by the maintenance department of the National Park Service, and the GPS antenna was attached with a magnet to the metal plate. With the elevated antenna, approximately one hundred fifty points were logged at regular intervals along the base of the cliff face.

After each data collection section, logged points were sent for differential correction via the internet to accessible bay stations in the region, such as Pueblo, Colorado and Pie Town, New Mexico. Trimble's Pathfinder® software was used for the differential correction process. Each data set was differentially corrected at least twice in order to compare the machine-logged locations, the corrected values, and known locations in the field. Point data collection and correction continued throughout the field season.

When a sufficient number of accurate points were placed in the GIS, polygons were created to represent full cavates on the computer screen. The software used in the field

was ESRI's ArcView 3.2®. Polygons were created through a two-part process. Dimensions of each cavate's existing opening were taken from the condition assessment forms and manually recorded on paper field maps. A laptop computer was brought into the field and, using the recorded dimensions, cavates were drawn onto the computer screen. This work was performed in the field in order to maintain a constant process of verifying spatial relationships between cavates.

Three Scales of Investigation

At a fine scale, every cavate has a particular set of attributes: location, condition, and a combination of natural and manmade features and embellishments. The extensive condition assessment performed in the 2002 summer field season recorded information about plaster finishes, masonry, mortar, and rock types, orientation, treatment recommendations, and treatment priority.⁶⁷ During the fall of 2002, the field assessment forms were entered into a relational database designed specifically for the cavate conservation project.

Every cavate was given a unique "cavate identification" number. This identifier is based on the cavate group, plus the panel within the group, and finally a three-digit number. Thus, cavate MJ100 refers to the cavate located in Panel J of Group M, and is specifically cavate 100. This record number was used consistently in field work, data preparation,

⁶⁷ The field assessment form is included in Appendix B.

and map analysis. Thus, any of the information contained within the condition assessment, stored in the Access® database, can be queried and selectively displayed to highlight spatial relationships among the cavates and specific conditions. Interior and exterior digital photographs of each cavate were included in the 2002 cavate survey, and have been incorporated in the GIS as “hotlinks” to the located polygons in order to present a more thorough graphic understanding of each cavate.

When Group M was surveyed in 1991 as part of the Bandelier Archaeological Survey, the group was divided into 19 smaller panels that roughly conform to the shifting contours of the cliff face. These defined panels serve as the basis for a second, slightly larger scale by which to study the cavates. When the cavates are seen as part of a cluster oriented in approximately the same direction, patterns of wind and water erosion can be examined. Cavates are often stacked one on top of another in the cliff face, and can also be joined from within through interior entrances. Treatments such as “drainage control,” prescribed for a single cavate, will likely affect the surrounding rooms. Geologic joints can slice through whole groups of cavates and allow water to enter otherwise protected areas. Individual cavate condition data can be combined with “neighborhood” level cluster data in order to examine relationships among small groups of rooms. This can be particularly useful in planning for treatment programs, as clusters of related conditions can be treated at once to minimize cost.

While Cavate Group M was selected as a test area to model in a GIS, its location within the larger landscape of Frijoles Canyon, as one of 13 documented cavate groups, is important to its state of conservation. Distance from available water, distance from pueblo settlements on the valley floor, and accessibility influenced function and periods of occupation among the groups. The physical and mechanical properties of the volcanic tuff throughout the Pajarito Plateau make it conducive to the creation of cavate structures, yet the rock does not weather at a constant rate. Deterioration patterns among and between groups of cavates can be investigated using a GIS that documents the location and condition of additional cavate groups. For example, a useful study could be to compare overall condition of cavates in Group M, which is accessible to the public, to that of Group A, one of the most visited of the cavate groups. Toll posed a number of spatial questions in his 1991 report, and hoped to compare data from different groups of cavates, as he explained in his published project report: “Within Frijoles Canyon we were interested in whether a number of locational variables influenced cavate morphology: upstream or downstream location within the canyon; vertical and horizontal proximity to the Rito; size of cavate group; location within a group.”⁶⁸

C.I.T.A. Project's 2002 Condition Assessment

A major focus of the summer 2002 field season was to complete a comprehensive condition assessment of each cavate within Frijoles Canyon. In contrast to earlier cavate

⁶⁸ Toll, page 17.

assessments and analysis, such as H. Wolcott Toll's study that resulted in the 1995 publication *An Analysis of Variability and Condition of Cavate Structures in Bandelier National Monument*, the C.I.T.A. project's 2002 condition assessment recorded information about physical condition as well as significance and conservation treatment priority.

The field assessment form, based on a form developed by Frank Matero for use in cavates of the Tsankawi section of Bandelier, is divided into five sections: *unit summary data*, *surface finishes*, *existing conditions*, *treatment recommendations*, and *previous documentation*. (See Appendix B) The *unit summary* section describes the location and physical characteristics of each cavate, such as orientation, dimensions, and type of tuff. This section also lists the extant features of the cavates, derived from a list compiled by Toll's previous study of the cavates.⁶⁹ In the *surface finishes* section of the form, finishes evident in the cavate – such as finish type, layer structure, and embellishments – are identified and described. The *existing conditions* portion of the form identifies presence or absence of specific conditions, as well as the degree to which symptomatic conditions of deterioration are present within each assessed cavate. Conditions were assessed separately for the rock substrate and for the finishes.

⁶⁹ Rivera et al, *Frijoles Canyon Cavate Pueblo Conservation Project and Field School in Site Conservation and Heritage Management: Interim Report*, pages 4-5.

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The conditions assessed that are indicative of structural deterioration are: loss of total original fabric, disintegration and friability, detachment, rock undercutting, and structural cracking. Additional existing conditions were recorded, including non-structural cracking (map-cracking in plaster finishes), presence of salts, partial loss of finishes, visible accretions, visible mechanical abrasion, graffiti, biological growth, and vegetation. Each condition is defined in a Glossary of Terms written to accompany the field assessment form, and is summarized in the chart below.

Definitions for Conditions Recorded in Cavate Group M	
Condition	Definition
Total Loss	Absence of original fabric based on total original extent of rock, masonry, or finishes.
Friability/Disintegration	Granular disintegration of rock or finishes.
Detachment	Voids between finish layers, at the rock/plaster interface, or within the rock.
Rock Undercutting	An undermining of rock that leaves an overhanging portion in relief; usually occurs on the ceiling near the cavates entrance.
Structural Cracking	Major (greater than 1 cm deep or 50 cm long) linear discontinuities in the rock or masonry, may include geologic joints.
Salts	Presence of salt crystals on surface of rock or finishes.
Mechanical Abrasion	Discrete areas of damage or loss caused by an external impact or force.
Graffiti	Modern , intentionally inscribed or applied markings on the rock or finishes.
Biological Growth	Presence of micro flora (algae, fungi, and/or lichen) on the surface.
Vegetation	Presence of larger plant forms, or evidence of plant roots, embedded in the rock or finishes.
Non-structural Cracking	Occurs in finishes only; loss of one or more layers from the existing finish, leaving earlier layers exposed. Occurs in layered finishes.
Partial Loss of Finishes	Portion of the surface finish missing.
Accretions	Discoloration of the rock or finishes caused by the addition of a substance such as mud flow or animal excrement. (Does not apply to soot.)

Table 4.1 *Definitions for Conditions Recorded in Cavate Group M.*

The severity of each condition was established based on the percent of total original fabric affected by the symptom. Severity was described as “insignificant” when less than ten percent of the total fabric of the cavate was affected; “low” when ten to twenty-five percent of the surface area or total fabric showed evidence of the condition; “moderate” if twenty-six to fifty percent of the cavate were affected; or “high” when greater than fifty percent of the cavate was affected by the condition. Numeric values from zero to three were assigned to each degree of severity; “insignificant” ratings were worth a zero score, and “high” severity conditions scored a three. Eight of the thirteen conditions assessed were considered particularly relevant to overall cavate condition or treatment priority, and were therefore weighted twice those of the other five conditions. For this reason, the condition values for “loss of total original,” “partial loss of finishes,” “disintegration and friability,” “detachment,” “rock undercutting,” “structural cracking,” “mechanical damage,” and “graffiti,” were multiplied by two in order to come up with a total condition score.

As discussed in Chapter 1, “significance” and “value” are difficult to quantify in any survey and assessment. Documents like the *Burra Charter* and the *Nara Document* seek to include the values of local stakeholders in the preservation planning process and the “Statement of Significance.” Cultural value and significance is approached in the cavate condition assessment through the *treatment priority* section of the field assessment form.

Native American input is a critical value to assess for this ancestral Pueblo site, but had not yet been incorporated into the field survey format.

Each cavate's relative significance is assigned a treatment priority value of high, medium, or low, based on the cavate's archaeological significance as well as the total condition score calculated in the *existing conditions* section of the form. High priority cavates are defined as "high priority for treatment due to significance of room (based on uniqueness of features, finishes schemes and/or embellishments), high percentage of intact structural materials, features and finishes, and low percentage of loss and/or deterioration of remaining materials."⁷⁰ In general, a sense of integrity and completeness in a cavate dictates its priority rating. An enclosed room with clearly articulated entrance stands as a record of construction techniques and provides a physical link with the past. However, other factors may also be considered in assessing a cavate's significance; evidence of "historic graffiti," left during the Spanish colonial period, for example, may add to the significance of a cavate.

The condition assessment conducted during the 2002 field season yielded a large amount of detailed information about many of the cavates in Group M; due in large part to the challenges presented by the steep terrain, not every cavate was surveyed. Of the one

⁷⁰ Cavate **significance** and **integrity** are essential to assigning treatment priority. **Significance** may be defined as: rooms with a high number of unique features, embellishments, or surface finishes schemes. **Integrity** relates to the amount of original fabric preserved in the cavate room, and is defined as: rooms of with a large number of original features, structural material, and finishes, and a low degree of deterioration.

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hundred sixty-six cavates identified on the digitized Group M elevation drawings, eighteen cavates were not assessed in 2002. Therefore, the condition assessment used in this case study refers to one hundred forty nine individual cavates.

The GIS created in the summer field season will be used as a framework in which to display and analyze the extensive data collected in the condition survey of Cavate Group M.

GIS DISPLAY AND ANALYSIS OF CONDITIONS IN CAVATE GROUP M

A primary goal of this thesis is to analyze information collected on the field condition survey in order to understand the combination of factors that lead to material deterioration of cavate structures. In this chapter I will examine ways a GIS may be used to symbolize data in order to visualize spatial distribution, concentration, and coincidence of symptoms of deterioration. In addition, factors that determine the physical context of each cavate will be compared to existing condition scores in order establish specific prerequisites for risk to cavate structures.

In this chapter I will use the GIS to display data from the field condition survey in the context of Frijoles Canyon. I will use the field survey form to create two broad categories of cavate information. The first category, *physical situation*, includes cavate orientation, exposure, context, size of opening, and presence of geologic joints. The second category of information collected is made up of *symptoms of deterioration* of the

rock substrate, such as total loss of original fabric, disintegration, rock undercutting, structural cracking, and mechanical deterioration. Cavates will be divided into three groups – high, medium, and low – of total condition scores. Each cavate situation will be compared to the overall condition of the cavate, based on the field survey data, in order to isolate those situations that correspond with particularly poor or good conditions. Relevant situations will then be compared to symptoms indicative of structural deterioration in order to identify patterns of symptoms and situations that may lead to damage in cavate structures.

GIS as a Framework for Data Display

The landscape of Frijoles Canyon may be described using a combination of color maps, three dimensional images, photographs, and scanned field notes and sketches; a GIS can serve as a useful tool with which to combine graphic and textual information collected throughout the C.I.T.A. project. In addition, a data display may be created for visitors as an introduction to the resources and landscape of the region, and can include maps of various scales, as well as photographs, movie clips, and slide shows.

Chapter Three emphasizes the care taken in the field to create a digitized base map that represents cavates as individual and measured polygons tied to geographic coordinates based on the standard datum used at Bandelier National Monument (NAD 27). The polygons, however, are more accurately described as points that represent the contour of

the cliff face in plan view. As such, it is perhaps most accurate to use points to represent each cavate in plan view, which may be placed over a layer of digital contour lines to provide a reference to elevation if necessary. Attributes may be added to the point layer for analysis. The point theme may also be “draped” over a three dimensional digital elevation model (DEM) in order to create the impression of cavates in the vertical rock wall of Frijoles Canyon. The existing DEM used at Bandelier is at a resolution that is too coarse to be used for extensive analysis at the cavate-level scale, but it does remain a useful means of understanding the location of Cavate Group M within the larger area of the Pajarito Plateau.

Field maps drawn of cavate elevations, as they appear when approached from the talus slope, remain the simplest form of identifying cavates from the ground. Although the existing field maps, based on field sketches and measurements taken in 1991 and traced into AutoCAD® in 1999, are not tied to geographic coordinates, they can still be brought into the GIS framework and used as descriptive graphics to annotate data displays.⁷¹ In addition, historic maps drawn by Kenneth Chapman on expeditions to the Pajarito Plateau conducted by Edgar L. Hewett in the first decades of the twentieth century depict

⁷¹ESRI's ArcMap® software allows vector drawings to be imported into the GIS. The vector cavate polygons were imported into the GIS as two distinct thematic layers – the west section and the east section of Group M – and then merged through the GeoProcessing tool available in ArcMap®. A new field was added to the attribute table of the imported polygons, and each polygon was given a unique identifier, known as a “cavate identification number.” Information from the condition survey attribute table is based on the same unique identifier, and can be joined to the newly created polygon attribute table based on the common field.

Frijoles Canyon using several points of perspective in order to suggest the depth of the canyon and the expanse of the mesa top. This image, like the DEM, gives a sense of the broad landscape as well as the relative location of each of the cavate groups within Frijoles Canyon; each of the images may be included in the GIS layout. (See Appendix C, Layout 1)

A series of interactive maps may be created for use in the Bandelier National Monument Visitor's Center or on a C.I.T.A. project website that allows visitors to examine the cultural resources of the area at different scales. "Hotlinking" is a tool available in ESRI's ArcMap® software that allows a user to point to a feature on the computer screen, click on the feature with a mouse and cause a new document to open and display information that relates directly to the selected feature. Thus, map documents may be created in which specific information is displayed at different scales, for example. Users may link to multiple documents, or use the "Information" tool (also available with ESRI® software) to display attributes of selected features. (See Appendix C, Layout 3)

Data display can help communicate and interpret data, and is integral to understanding large amounts of data. This is critical for the C.I.T.A. project, in which large amounts of data are collected in the field and interpreted after the field season. A GIS serves as a tool to better understand the relationship between the landscape of Frijoles Canyon and

the combination of factors that determine the stability and condition of cultural resources at Bandelier.

Physical Context and Symptoms of Risk

An important focus of the field survey of cavate condition is to gain a better understanding of the combination of physical, mechanical, and environmental factors that lead to material deterioration. A GIS can be used to break extensive condition data into manageable layers of component parts.

Due to the friable nature of volcanic tuff, cavates are threatened by erosion caused by wind, rain, human disturbance, and inherent properties of the tuff. Cavate Group M is inaccessible to visitors to the Monument, therefore human disturbance will not be examined as a factor that leads to risk in this case study; if, however, additional cavate groups are incorporated into the GIS at a later date, visitor traffic and proximity to trails will be a critical factor to record and analyze. Factors such as slope of the talus hillsides, elevation on the cliff face, hydrology, ground permeability, freeze-thaw patterns, and prevailing wind direction and speed are also important factors to investigate, though beyond the scope of this thesis. In this section of the GIS analysis, I will focus on wind and water as sources of cavate deterioration, and will seek to understand how landscape, cavate location, and cavate features lead to conditions that indicate active deterioration. Through a better understanding of the relationship among physical features and

GIS ANALYSIS OF CONDITIONS IN CAVATE GROUP M

symptoms of deterioration evident in present conditions. I hope to prioritize remedial treatment in order to minimize future damage due to weathering.

The descriptive condition survey conducted in 2002 recorded information about existing “symptomatic” conditions, such as mechanical deterioration, disintegration, and rock undercutting. In addition, the “situations” – such as size of cavate opening, presence of geologic joints, and exposure – that define the local area of individual cavates were surveyed. Based on field observations and known physical properties of Bandelier Tuff, the hypothesis tested in this thesis is that there exists a pattern of “situations” that leads to active deterioration, which is reflected in symptomatic conditions present in a cavate. Each of the existing conditions – symptoms of risk – has a set of associated causes, as outlined in the table below. Any combination of causes may result in symptoms that indicate a degree of material deterioration.

Symptoms of Risk Recorded in Cavate Group M	
Symptom	Causes
Total Loss	Water, Wind, Geology, Salts, Humans
Friability/Disintegration	Water, Salts, Humans
Detachment	Water, Salts
Rock Undercutting	Water, Wind, Geology
Structural Cracking	Geologic Fabric, Joints, Seismic Activity
Salts	Water, Inherent Properties of Tuff
Mechanical Deterioration	Wind, Humans
Graffiti	Humans
Biological Growth/Vegetation	Water, Sunlight, Slope

Table 5.1 *Symptoms of Risk Recorded in Cavate Group M.*

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All nine of the recorded existing conditions described in the field survey form may be considered symptoms of risk. Although plaster finishes are an important feature of the cavate structures, mechanisms and symptoms of deterioration of plaster finishes were not considered in this thesis. This thesis isolates five symptoms, highlighted in red in the table above, which relate to structural deterioration that is influenced by a cavate's physical context: total loss of original fabric, friability and disintegration, detachment, rock undercutting, and structural cracking. The degree to which each symptom is present was recorded in the field survey using a scale of one to four, such that one indicates the minor presence of a specific symptom, and four suggests that the symptom is present in a majority of the cavate. The degree of symptomatic conditions present allows for a nuanced exploration of the relationship between individual symptoms and physical context of each cavate.

There are six features recorded in the *unit summary section* of the field survey form that relate directly to a cavate's permeability to wind and water: size and orientation of the cavate opening, cavate exposure, type of rock excavated in construction, cavate context, and the presence or absence of geologic joints. These six features can be considered the cavate's physical context or "situation." The chart below describes the six "situations" recorded in the *unit summary section* of the field survey form. Surveyors selected the appropriate context from several options provided in each section.

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Situations Recorded in Cavate Group M	
Cavate Situations	Description/Form Options
Exposure	Open or Protected
Orientation	Direction of Existing Opening, Based on Decimal Degrees
Type of Rock	Tschirege or Otowi Tuff
Cavate Context	Isolated, Cluster, Continuous
Geologic Joints	0-4 Joints Present
Opening Dimensions	Total Area of Opening (Meters ²)

Table 5.2 *Situations Recorded in Cavate Group M.*

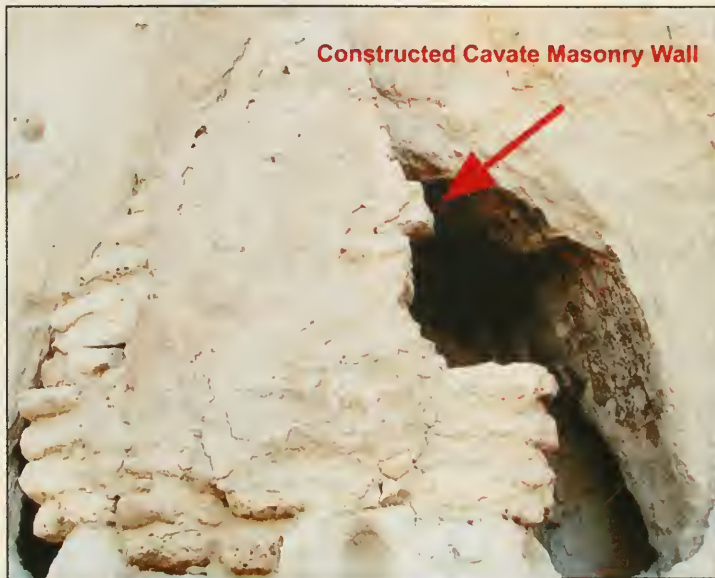


Figure 5.1 *Cavate MJ092, considered "protected," with a masonry wall.*



Figure 5.2 *Cavate MJ100: Isolated and open.*

In the *unit summary* section, the exposure of each cavate is listed as either “open,” or “protected.” “Open” cavates refer to cavates that have lost the walls that surround constructed entrances, and are now more than fifty percent exposed. “Protected” cavates retain at least fifty percent of the masonry walls of the entrance segment. The “orientation” of each cavate was recorded with a standard compass, using true north and decimal degrees, standing in a

cavate opening and facing outward toward the canyon. While the orientation measure does not necessarily reflect the original orientation of the constructed entrance, it represents the direction that the existing opening now faces. The “type of rock” for each cavate is recorded on the survey form, although all of the cavates within Frijoles Canyon are of the Tschirege type of

Bandelier Tuff. If the GIS framework is expanded at some point in the future to include cavates in the Tsankawi section of Bandelier, the type of rock substrate – Tschirege or Otowi tuff – will be a critical factor to consider, as the two varieties deteriorate at different rates. “Cavate context” may be isolated, as a singular unit with no adjacent neighbors, shared walls, or shared floors; part of a cluster, which is made up of two or more cavate units in close proximity to another; or contiguous, when clustered cavates are linked through interior openings or entrances.

“Geologic joints” are structural cracks in the cliff face that define or intersect the cavate, and may conform to the contour of the cliff face. Finally, the “opening dimensions” were recorded based on the total area of the cavate exposed to the canyon. Extant cavate openings may be quite different than the original constructed entrances, which, in some cases were built with masonry units of mud brick and talus.

Condition Scores

The total condition values derived from the field condition survey, described in Chapter 3, are based on a weighted scoring system that includes both additive conditions, such as accretions and vegetation, and subtractive conditions such as disintegration and detachment. The weighted system was developed in previous cavate documentation projects by architectural conservators at Bandelier. Condition scores for symptoms considered particularly dangerous – or in the case of graffiti, straightforward to treat in

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regular maintenance programs – are weighted twice that of other recorded symptoms.

Symptoms that receive weighted scores are: loss of total original fabric, disintegration, detachment, rock undercutting, structural cracking, mechanical damage, and graffiti. The remaining symptoms (salts, accretions, biological growth, and vegetation) are not weighted in the assessment.

Weights Assigned to Symptoms For Total Condition Value	
Symptom	Weight
Loss of Total Original	x2
Disintegration/Friability	x2
Detachment	x2
Rock Undercutting	x2
Structural Cracking	x2
Salts	x1
Accretions	x1
Mechanical Damage	x2
Graffiti	x2
Biological Growth/Vegetation	x1

Table 5.3 *Weights Assigned to Symptoms for Total Condition Value.*

Of the seven weighted condition scores, total loss of original fabric occurs most often, followed by disintegration/friability, structural cracking, and rock undercutting.

High condition scores indicate a greater level of damage to the physical fabric of the cavate room.⁷² The survey form provides a total condition score based on the sum of

⁷² Because the score for each individual condition is based on the percentage of wall or finish affected by the condition, the score is most applicable to those cavates in a state of active deterioration. It is possible, for example, for a cavate that is so deteriorated that it has lost whole wall segments to receive a relatively low

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condition scores reported for each symptom (such as total loss, friability, detachment, and rock undercutting) as it appears on both the plaster finishes and the rock substrate. This thesis will not analyze the specific cause and effect relationships among symptoms associated with plaster finishes, but will focus on those areas where plaster once existed, and the current condition is now considered a “rock substrate” condition rather than a “surface condition.”

The format of the field survey allows for the arbitrary creation of three categories of condition score, grouped as “high,” “medium,” and “low.” Total condition scores range from two to fifty-three, where two represents cavates in the best condition and fifty-three is the cavate in the most deteriorated state. A histogram displays the numeric distribution of condition scores by plotting the frequency of total scores against total condition values. The graph indicates that most of the scores, 111 of 148 surveyed cavates, are concentrated in the range of 14.75 to 36.

score. If there is no remaining ceiling, there will be no condition score for that section of the cavate, which will lower the total score for the room.

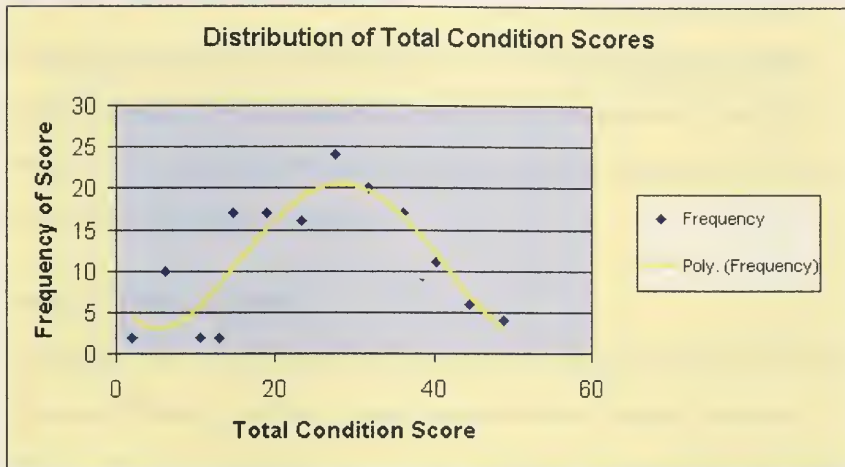


Figure 5.3 *A histogram displays the distribution of total condition scores.*

Based on the distribution of total condition scores, the three groups of condition break down into the following three categories: high condition value, including those cavates with a total condition score of greater than 36; medium condition value, which includes those cavates with a total condition value in the range of 14.75 to 36; low condition value, made up of cavates with a total condition score of less than 14.75. An initial map query shows the spatial distribution of condition categories. (See Appendix C, Layout 4)

As the map indicates, cavate condition scores are generally distributed evenly across the area of cliff face that comprises Group M. The map does display, however, that panels K, L, M, N, and P make up a continuous stretch of cliff face in which all of the cavates

have low or medium condition scores; these scores indicate that none of the cavates in this stretch are in severely deteriorated condition. In addition, panels H and I contain cavates of “medium” overall condition; no cavate in these two panels received a “high” condition score. In general, those cavates in the east section of Cavate Group M receive lower – better – total condition scores.

Presence of Symptoms of Risk

A GIS may be used to display condition information about Group M, based on the survey information collected in the field, to present current conditions recorded for the rock substrate. The series of symptom maps provides a reference for conservators, and can be printed and brought to the field in order to locate specific cavates. For this reason, the presence or absence of each recorded condition is displayed on an image of cavate elevations which is not based on geographic coordinates, but rather the digitized field map imported into the GIS. The queries displayed in the first stage of maps illustrate the presence and locational distribution of nine conditions recorded in the Cavate Group M. Conditions mapped include: loss of original fabric, disintegration and friability, detachment, rock undercutting, structural cracking, salts, mechanical damage, graffiti, and vegetation. (See Appendix C, Layouts 5,6,7)

Frequency of Symptoms Present in Cavate Group M	
Symptom	Percentage of Cavates with Symptom Present
Total Loss of Original Fabric	88.40%
Friability/Disintegration	81.60%
Detachment	4.10%
Rock Undercutting	39.50%
Structural Cracking	55.80%
Salts	0.00%
Mechanical Damage	19.70%
Graffiti	1.40%
Vegetation	1.40%

Table 5.4 *Frequency of Symptoms Present in Cavate Group M.*

Once again, the map layouts indicate that conditions are evenly distributed across the cliff face. “Total loss of original fabric” is the most widely reported existing condition in Cavate Group M, and was recorded in 88 percent of surveyed cavates. This high figure is likely a cumulative effect of the other subtractive conditions surveyed, such as disintegration, detachment, and rock undercutting; as these conditions accumulate, total loss of original fabric increases. In addition to total loss, disintegration, rock undercutting, and structural cracking are the conditions that occur most frequently in surveyed cavates. Each of these symptoms is a weighted condition on the field survey form, thus scores for each category range from zero (when the condition is not present in the surveyed cavates) to six (the symptom is present to a severe degree in the cavate).

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The four symptoms that occur most frequently in Cavate Group M – total loss, disintegration, rock undercutting, and structural cracking – were examined in order to determine whether the symptoms are associated with severe condition scores. Scores greater than or equal to four may be considered “severe.” 75 percent of the 130 cavates with recorded “total loss” of the rock substrate received a severe rating. The symptom of structural cracking also tends to receive a severe score: 55 percent of the recorded cavates with structural cracking were rated with a score of four or greater. Rock undercutting and friability tend to receive slightly lower condition scores, though nearly half of the instances of rock undercutting were recorded as severe.

Severity of Prevalent Symptoms Present in Cavate Group M	
Symptom	Percentage of Scores of 4 or Above (Severe)
Total Loss of Original Fabric	75.30%
Friability/Disintegration	37.10%
Rock Undercutting	48.20%
Structural Cracking	55.00%

Table 5.5 *Severity of Prevalent Symptoms Present in Cavate Group M.*

Cavate Situation

In order to better understand the role that situation plays in the deterioration of cavates, a group of queries compares cavate situation with each of the three condition categories, high, medium, and low. Maps that overlay each cavate situation, represented with color coded points, on a thematic layer of cavate total condition scores (colored red, yellow, and green to represent high, medium, and low condition scores) present information

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about correlations between physical context and existing condition. Map layouts examined in this section compare total condition category with: cavate exposure, cavate context, number of geologic joints present in each cavate room, and orientation of existing cavate openings. (See Appendix C, Layouts 8, 9, 10, 11)

Cavate exposure – protected or open – directly relates to the amount of wind and water that enters a cavate, and may correlate with a high overall condition score. Most of the cavates surveyed are considered “open.” 16 of the 147 surveyed cavates, or 10.8 percent, were considered “protected” cavates. As the map shows, protected cavates are distributed over the cliff face, concentrated in cavate panels F-J and in the center of Group M. (See Appendix C, Layout 8)

In the west section of Group M, protected cavates are located in rooms with low and medium condition scores. Several cavates high up on the cliff face were surveyed from the ground, and do not have complete condition scores, although they were judged from the ground as protected in exposure. The highest concentration of protected cavates in the west half of Group M is found in Panel E, which also has a high number of inaccessible cavate rooms. Cavates in Panel E are protected due to rock overhangs and protected contours of the cliff face, as seen in the plan view. In the east section of Group M, however, cavates recorded as “protected” were found primarily within Panel J. These cavates seem to have been considered “protected” in exposure due to the presence of

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constructed masonry walls, rather than the natural contours of the canyon wall. Only one of the protected cavates is in the “high condition” category, civate MJ092. Cavates in Panel J are accessible, and tend to have existing features such as plaster embellishments. That these cavates are considered “protected” is an anomaly, as they are among the few cavates with extant masonry walls. Presence of constructed enclosures may have influenced ratings assigned in field surveys. -

There is a strong indication that cavates with exposed existing openings are in the high condition category: of the 23 cavates with high condition scores, only one civate was considered “protected” in the field survey.

The context of individual cavates can determine how wind and water pass through or penetrate a group of rooms. Most of the excavated cavates in Group M are grouped as either clustered – in close proximity to one another – or contiguous – clustered rooms connected by interior openings. Two cavates, less than two percent of the surveyed cavates, were recorded as isolated rooms. 66 cavates, approximately 46 percent, are contiguous cavates; the remaining seventy-four surveyed cavates, 52 percent, are clustered rooms.

Spatial queries performed with the “select by location” function of the ArcMap® software bases feature selections for one thematic layer on feature locations of a second

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thematic layer. The query language may be constructed as follows: “Select features from the ‘Contiguous Cavates’ thematic layer that intersect features from the thematic layer ‘High Condition Score.’” The graphic results are useful in order to understand the significance of cavate context. While the majority of cavates are clustered, only 11 percent of those cavates fall within the highest condition score. Cavates that are contiguous, a subcategory of clustered rooms, are more likely to fall within the high condition score than are clustered or isolated cavates. 24 percent of all contiguous cavates have high total condition scores. Of the 16 contiguous cavates with high condition scores, all but two are located in the West section of Group M. (See Appendix C, Layouts 13 and 14)

Geologic joints may be visible in areas of the cleavage in the cliff face; these areas may serve as a means of water ingress, and may also indicate areas of seismic shifts. Presence or absence of joints, as well as the number of joints present in cavate rooms were recorded for one hundred sixty three of the cavates in Group M. According to the field survey, no cavate in Group M has more than two geologic joints, and most – 127 cavates – have zero geologic joints. 29 cavates, or nearly 18 percent of cavates surveyed, have a single geologic joint recorded.

Through the use of the “select by location” query method, a possible relationship emerges between the number of geologic joints present in cavates and the total condition score.

Of the seven cavate rooms with two geologic joints, three (43 percent) fall within the high condition score range. One cavate with a single geologic joint present has a high condition score, and fifteen, or twelve percent, of the rooms with zero joints were high scoring cavates. These percentages suggest that presence of two geologic joints leads to a high condition score, and that a lack of joints suggests that a low or medium condition score will be assigned to a cavate room. However, field observations indicate that there are more geologic joints present in the cliff face and associated with cavates than the field survey suggests. It is likely that there is some discrepancy in field recording of geologic joints. (See Appendix C, Layouts 17 and 18)

Cavate orientation was recorded in the field based on the direction each existing cavate opening faces out toward Frijoles Canyon. Aspect readings were taken in decimal degrees, based on true north, and information was recorded for 141 cavates. Cavate orientation ranged from 136 degrees (roughly northeast) to 286 degrees (roughly northwest). Field observations indicate that wind-distributed talus and particles are a cause of deterioration in cavates; therefore, the orientation of a cavate's existing opening may be an important factor in assessing risk.

8 Categories of Cavate Orientation	
Decimal Degree	Orientation Category
0-45 Degrees	Northern Northeast
46-90 Degrees	Southern Northeast
91-135 Degrees	Northern Southeast
136-180 Degrees (present in Group M)	Southern Southeast
181-225 Degrees (present in Group M)	Southern Southwest
226-270 Degrees (present in Group M)	Northern Southwest
271-315 Degrees (present in Group M)	Southern Northwest
316-360 Degrees	Northern Northwest

Table 5.6 8 Categories of Cavate Orientation.

A majority of the cavates surveyed (55 percent) face southwest. Among cavates that face southwest, 63, or 45 percent, fall in the “northern southwest” category, and 46 cavates (33 percent) are in the “southern southwest” group. The map presented in Figure ___ eastern edge of the study area, where most of the cavates face southeast. (See Figure 11)

The dense cluster of cavates that face southeast in Panels P and Q merits close investigation, as there appears to be a correlation between orientation and “good” (low or medium) condition. 20 face southeast, and 85 percent of those cavates have low or medium condition scores. Of the 33 cavates in the low condition score category, 21 percent face southeast. Therefore, if a cavate opening faces southeast, it will likely remain in fairly good condition. (See Appendix C, Layout 11)

Dimensions of existing openings are perhaps the most direct means of ingress and egress of water and wind into the cavate room. Opening sizes were measured using centimeters

in the field, and are described in square meters in this thesis. Dimensions used in this analysis should be confirmed in the field; cavates and their existing openings are by nature of irregular shape and in a constant state of erosion. It is difficult to calculate an exact dimension of existing openings, and surveyors often recorded dimensions in different areas of the cavates. Some dimensions included in this section may have been recorded in the interior of the cavate room rather than at the existing opening.

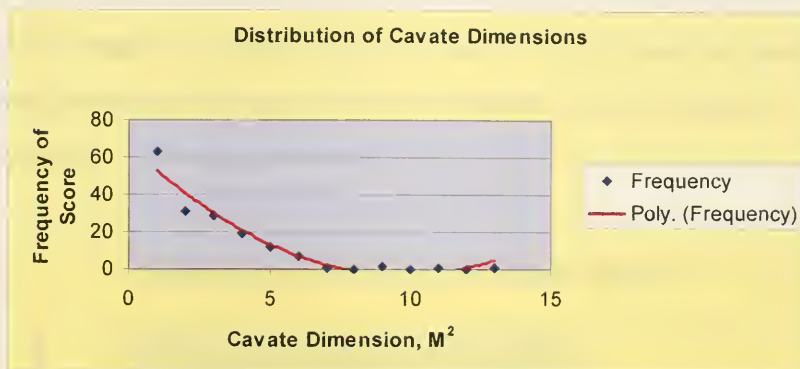


Figure 5.4 The histogram shows the distribution of cavate opening dimensions.

Dimensions recorded in Cavate Group M range from 0.1 square meters to 18.27 square meters. As the histogram below illustrates, most of the cavate openings (55 percent) range in size from 1.5 to six square meters.

In order to categorize the cavate dimensions, cavate dimensions have been divided into three groups: small dimensions (zero to three square meters), medium dimensions (three

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to 4.5 square meters), and large dimensions (greater than 4.5 square meters). 123 cavates fall within the small cavate category, 17 cavates are in the medium dimension group, and there are 24 large cavates.

Large opening dimensions correlate with high and medium condition scores. Of the 24 cavates with large opening dimensions, eight cavates (33 percent) have high total condition scores, 15 (63 percent) have medium total condition scores, and one cavate (four percent) has a low condition score. By contrast, 31 of the 123 cavates with small opening dimensions (25 percent) also have a low condition score. (See Appendix C, Layout 12)

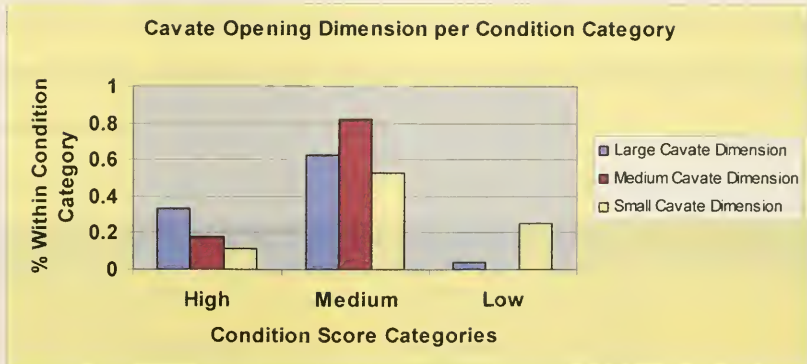


Figure 5.5 The bar graph displays the cavate opening dimension size per condition category.

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As the graph above shows, most of the cavates in the high condition score category are cavates with large openings. In addition, most cavates in the low condition score group have small opening dimensions.

By mapping each cavate's situation separately, and then adding a thematic layer that displays the three categories of total condition, general correlations emerge that link cavate context with state of conservation, as described in the table below. Cavates located in the east half of the canyon wall of Cavate Group M tend to be in better overall condition than those rooms in the west section of the area. Cavates recorded as facing southeast, protected in exposure, or isolated in context tend to fall within the low or medium condition categories. Cavates with more than one geologic joint, those that face southwest, or are clustered in contiguous cavate rooms tend to have higher total condition scores. Cavates with large openings often have high condition scores and rarely have low condition scores.

If/Then Correlations Between Cavate Situation and Condition Categories	
Situation	Condition Tendency
Protected Exposure	Low/Medium Condition Score
Isolated Context	Low/Medium Condition Score
Small Opening Dimension	Low/Medium Condition Score
Southeast Orientation	Low/Medium Condition Score
Contiguous Context	High Condition Score
Southwest Orientation	High Condition Score
2 Geologic Joints	High Condition Score
Large Opening Dimension	High/Medium Condition Score

Table 5.7 *If/Then Correlations Between Cavate Situation and Condition Categories.*

Comparison of Cavate Situation and Symptoms

As described above, cavate situation and symptoms of deterioration are recorded separately on the field assessment form. In order to better understand the combination of situations and symptoms that serve as prerequisites of risk, cavate symptoms will be compared to those cavate situations established as related to high condition scores.

Cavate symptoms which occur most frequently and are associated with the highest condition scores (total loss of original fabric, friability/disintegration, rock undercutting, and structural cracking) will be compared to those cavate situations (large opening dimensions, two geologic joints, southwest orientation, and contiguous context) also identified as prevalent in rooms with high condition scores.

67 cavates are recorded as contiguous in context; all but one of those 67 cavates also has some level of recorded total loss of original fabric. In addition, 48 (72 percent) of contiguous cavates have a severe score (greater than four) recorded for total loss. 13 of the 48 contiguous cavate rooms with severe total loss scores fall within the high condition category. Many contiguous cavate rooms are also recorded as having a severe amount of disintegration of original rock substrate. 27 contiguous cavate rooms (40 percent) have a severe disintegration score. Of that 27, nine cavates (33 percent) fall in the high total condition score category. Rock undercutting, a condition that leads to collapse of the room ceiling, occurs in 10 contiguous cavates, or 15 percent of contiguous cavate rooms.

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There are four contiguous cavate that have both high total condition scores and severe rock undercutting. Finally, 22 (nearly 33 percent) of the 67 contiguous cavates are recorded as having a severe degree of structural cracking; 11 of the 22 (50 percent) fall within the high condition category. (See Appendix C, Layouts 13 and 14)

Comparison of Contiguous Cavates, Severe Symptoms, and High Condition Category			
Situation	Symptom Present	Situation + Severe Symptom Rating	Situation + Severe Symptom + High Condition Score
Contiguous Cavates (67 Total)	Total Loss	72%, 48 of 67	27%, 13 of 48
	Friability/Disintegration	40%, 27 of 67	33%, 9 of 27
	Rock Undercutting	15%, 10 of 67	40%, 4 of 10
	Structural Cracking	33%, 22 of 67	45%, 10 of 22

Table 5.8 *Comparison of Contiguous Cavates, Severe Symptoms, and Condition.*

Most of the cavates in Group M face southwest: 109 cavates surveyed are in the southwest cavate orientation category. While 28 percent (31 cavates) of rooms that face southwest show severe structural cracking, only one third of those 31 cavates have severe structural cracking and also fall into the high condition category. There are also 31 southwest facing cavates recorded as having a severe degree of disintegration/friability; of those 31 cavates, nine (29 percent) are in the high condition score category. Severe rock undercutting is recorded in a smaller percentage of southwest facing cavates: 19 of 109 cavates, or 17 percent. Of that 17 percent, five cavates (29 percent) also fall in the high condition score category. A majority of cavates that face southwest – 72 cavates, or

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66 percent – score in the severe range for total loss of original fabric: 18 percent of those 72 cavates (13 rooms) score a high condition rating. (See Appendix C. Layouts 15 and 16)

Comparison of Southwest Facing Cavates, Severe Symptoms, and High Condition Category			
Situation	Symptom Present	Situation + Severe Symptom Rating	Situation + Severe Symptom + High Condition Score
Southwest Facing Cavates (109 Total)	Total Loss	66%, 72 of 109	18%, 13 of 72
	Friability/Disintegration	28%, 31 of 109	29%, 9 of 31
	Rock Undercutting	17%, 19 of 109	26%, 5 of 19
	Structural Cracking	28%, 31 of 109	35%, 11 of 109

Table 5.9 *Southwest Facing Cavates, Severe Symptoms, and High Condition.*

Although the presence of two geologic joints tends to indicate a high condition score, only seven cavates in Group M are recorded as having more than one geologic joint.⁷³ Five of the seven cavates (71 percent) have severe friability/disintegration recorded in the cavate rooms, and three cavates have both severe disintegration ratings and high total condition scores. There are also five cavates with a severe degree of total loss of original fabric recorded, two of which fall within the high total condition score category. Two cavates, both in Panel J, have two geologic joints and severe rock undercutting. One cavate (MJ095) has two geologic joints, severe rock undercutting, and falls into the high condition score group. Once again, five of the seven cavates with two geologic joints

⁷³ There appears to be a discrepancy between definitions of geologic joints on the field survey form. Although only seven cavates are recorded as having two or more geologic joints present, field observations suggest there should be a far greater number recorded. This data, as with the dimensions of cavate openings, should be field-checked.

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also have a severe symptom score for structural cracking. Two of those cavates received high total condition scores. Not surprisingly, both cavates are also in Panel J. (See Appendix C, Layouts 17 and 18)

Comparison of Cavates with 2 Geologic Joints, Severe Symptoms, and High Condition Category			
Situation	Symptom Present	Situation + Severe Symptom Rating	Situation + Severe Symptom + High Condition Score
2 Geologic Joints (7 Total)	Total Loss	71%, 5 of 7	40%, 2 of 5
	Friability/Disintegration	71%, 5 of 7	60%, 3 of 5
	Rock Undercutting	29%, 2 of 7	50%, 1 of 2
	Structural Cracking	71%, 5 of 7	40%, 2 of 5

Table 5.10 *2 Geologic Joints, Severe Symptoms, and High Condition Scores.*

As mentioned above, 24 cavates have large opening dimensions. Seven of the 24 cavates (29 percent) have severe rock undercutting recorded in the room. Three of the seven cavates (43 percent) also have high total condition scores. Structural cracking is recorded as severe in half of the 24 cavates with large opening dimensions, and seven of the 12 (58 percent) are also in rooms with high total condition scores. 11 cavates have large openings and severe total loss of original fabric. Six of the 11 cavates satisfy both the large opening dimension and high condition criteria. Finally, eight of the 24 cavates (one third, or 33 percent) with large opening dimensions have severe friability/disintegration recorded on the field assessment form. Five of the eight cavates (63 percent) are within the high total condition score category. (See Appendix C, Layouts 19 and 20)

Comparison of Large Opening Dimensions, Severe Symptoms, and High Condition Category			
Situation	Symptom Present	Situation + Severe Symptom Rating	Situation + Severe Symptom + High Condition Score
Large Cavate Dimensions (24 Total)	Total Loss	46%, 11 of 24	55%, 6 of 11
	Friability/Disintegration	33%, 8 of 24	63%, 5 of 8
	Rock Undercutting	29%, 7 of 24	43%, 3 of 7
	Structural Cracking	50%, 12 of 24	58%, 7 of 12


Table 5.11 *Large Opening Dimensions, Severe Symptoms, and High Condition Scores.*

Results of Analysis and Assessment of Risk

Each of the cavates excavated into the wall of Frijoles Canyon is in an active state of deterioration due to the material properties of volcanic Bandelier tuff. The rate and degree of damage to individual cavate rooms depends on the cavate's situation as well as its symptoms of deterioration. This chapter uses a GIS in which the field survey data were combined with digital photographs to analyze the condition of cavates in Group M. Cavate situations and symptoms were examined separately, and then digitally overlaid on one another as thematic layers in order to understand combinations of physical context and existing conditions that lead to high condition scores and poor overall condition of the room. Data associated with geologic joints will not be included in the final assessment of cavate risk, as only seven rooms were recorded as having more than one geologic joint.

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Contiguous cavate rooms, southwest facing rooms, cavates with large opening dimensions, and cavates with two geologic joints tend to score in the high condition category. Most cavates are recorded as having total loss of original fabric, friability and disintegration, and structural cracking. Total loss and structural cracking tended to receive high scores in the field survey. Severe structural cracking, severe total loss of original fabric, and severe friability/disintegration are the three symptoms that, when combined with the situations associated with high condition scores (contiguous cavate rooms, southwest facing rooms, and cavates with large opening dimensions) lead to high total condition scores for the cavate room. These findings are detailed in the chart below.



Comparison of Cavate Situation, Severe Symptoms, and High Condition Category			
Situation	Symptom Present	Situation + Severe Symptom Rating	Situation + Severe Symptom + High Condition Score
Contiguous Cavates (67 Total)	Total Loss	72%, 48 of 67	27%, 13 of 48
	Friability/Disintegration	40%, 27 of 67	33%, 9 of 27
	Rock Undercutting	15%, 10 of 67	40%, 4 of 10
	Structural Cracking	33%, 22 of 67	45%, 10 of 22
Southwest Facing Cavates (109 Total)	Total Loss	66%, 72 of 109	18%, 13 of 72
	Friability/Disintegration	28%, 31 of 109	29%, 9 of 31
	Rock Undercutting	17%, 19 of 109	26%, 5 of 19
	Structural Cracking	28%, 31 of 109	35%, 11 of 109
2 Geologic Joints (7 Total)	Total Loss	71%, 5 of 7	40%, 2 of 5
	Friability/Disintegration	71%, 5 of 7	60%, 3 of 5
	Rock Undercutting	29%, 2 of 7	50%, 1 of 2
	Structural Cracking	71%, 5 of 7	40%, 2 of 5
Large Cavate Dimensions (24 Total)	Total Loss	46%, 11 of 24	55%, 6 of 11
	Friability/Disintegration	33%, 8 of 24	63%, 5 of 8
	Rock Undercutting	29%, 7 of 24	43%, 3 of 7
	Structural Cracking	50%, 12 of 24	58%, 7 of 12

Table 5.12 Comparison of Situation, Severe Symptoms, and High Condition Scores.

Based on the condition comparisons summarized above and displayed in the Map Appendix, an assessment of risk may be made as follows: cavates that combine large opening dimensions, contiguous cavate rooms, or southwestern orientation with a severe degree of total loss of original fabric, friability/disintegration, or structural cracking are likely to deteriorate to a greater degree than those cavates that do not satisfy those criteria. Cavates which display the combination of factors that have been determined to lead to severe deterioration may be considered at greater risk. Based on this conclusion, conservators may prioritize treatment such that those cavates that satisfy the criteria for

GIS ANALYSIS OF CONDITIONS IN CAVATE GROUP M

risk but show a low total condition score receive preventive care, as they are most likely to deteriorate to a severe degree in the future.

6

CONCLUSIONS

Bandelier National Monument is a site layered with significance that derives from its natural and cultural resources. Preservation of the architectural ruins, cultural artifacts, and natural landscape that make Bandelier a site of “historic and scientific interest” has been the management focus since its designation as a National Monument in 1916. Stakeholders in the site include local pueblo communities, archaeologists, naturalists, cultural resource managers, and tourists; thus, a multi-disciplinary and multi-cultural approach to conservation planning and intervention is essential. The C.I.T.A. cavate conservation project brings together students and professionals to develop a conservation strategy that incorporates inclusive notions of value and significance. It is my goal in this thesis to present an assessment of risk for Cavate Group M which compares the physical context and location of cavates to existing symptoms of deterioration. The risk assessment will allow cultural resource managers to initiate preventive treatment in order to extend the physical life of an important, tangible record of ancestral Puebloan culture.

Chapter 2 outlines the role that “risk” plays in cultural resource management; identifying monuments and sites at risk allows conservators to move to a model of preventive rather than remedial treatment. Risk, in this case, may be defined as anything that threatens the longevity of a site. In Frijoles Canyon, specific combinations of existing conditions and cavate context lead to a high degree of damage. This thesis identifies the relationship between cavate context and recorded symptoms that poses the highest risk for loss of a significant resource. The assessment of risk is presented in Chapter 5.

Recommendations for Further Research

The analysis presented in this thesis represents a middle range of investigation of cavate condition, in order to establish a geographic framework for field survey data. Additional analysis at a courser resolution that incorporates the hydrology of the Pajarito Plateau and Frijoles Canyon, as well as hillside slope, regional weather conditions, geologic history, and seismic patterns could lead to a better understanding as to how cavate location impacts mechanisms of decay in Bandelier Tuff.

Natural and human causes result in material deterioration of cavate structures. Water, wind, geology, salts, seismic activity, slope, and humans are some of the factors that lead to cavate damage. This thesis explores ways in which wind and water cause cavate deterioration; further research that incorporates the impact of tourism is an important component to investigate. A study in which trails, paths, and public accessibility are all

mapped and compared with total condition scores for cavate groups that are within public areas of the park could provide valuable insight about human causes of deterioration.

At a finer scale, individual conditions could be mapped within a single cavate in order to better understand relationships among discreet conditions. In particular, a more nuanced use of GIS in a single cavate could map the location of features such as geologic joints, structural cracking, and vegetation in order to make explicit correlations between physical context, existing conditions, and deterioration. This research component could make more extensive use of GIS operations that use raster-based spatial analysis to understand how conditions spread or migrate through cavate rooms or cavate clusters.

This thesis has taken the recorded physical “situation” for each cavate as the basis of for comparison with the symptoms of deterioration present. Further studies could be based on recorded existing conditions – the “symptoms of deterioration” – in order to better understand individual factors that comprise the “total condition” score for each cavate. Severe “total loss,” for example, tends to be a cumulative condition predicated on the presence of other conditions, such as structural cracking and friability. Research undertaken to better understand the conditions that lead to severe total loss would be beneficial in formulating a Priority Treatment Schedule.

Recommendations for Data Collection

Based on the analysis of cavate situations, the size of opening dimensions of cavate rooms are a critical factor in determining risk. Opening dimensions, based on maximum height and maximum width of the existing opening should be measured for each cavate. This process needs to be standardized in the field. Presence of geologic joints could also be an important aspect to consider in a more standardized manner. Field condition surveys are focused on individual cavate rooms, therefore geologic joints that slice through large panels of the canyon wall may be overlooked when surveyors are examining the interior surfaces of discreet cavates.

Conclusions

Wind, water, and the inherent properties of Bandelier Tuff cause erosion and threaten cavate structures in Frijoles Canyon. Two categories of data collected in the field condition survey provide information about cavate deterioration: **physical situation**, which includes cavate orientation, exposure, context, size of opening, and presence of geologic joints; and **symptoms of deterioration**, such as loss of original fabric, disintegration, rock undercutting, and structural cracking. When the two groups are compared in the GIS, a clear relationship emerges. There is a higher frequency of high (severe) condition scores in cavates of specific orientation, exposure, context, and opening dimensions. These specific situations favor water and wind ingress. The

resultant poor total condition can be directly attributed to water- and wind-based phenomena.

A risk assessment may be derived from an analysis of surveyed conditions and context in order to prioritize conservation treatment. In the future, cavates that display the prerequisites for damage identified in this thesis – large opening dimensions, southwest orientation, interconnected entrances between rooms, as well as severe structural cracking, severe loss of original fabric and friability – may be of high treatment priority in order to prevent damage before it occurs.

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APPENDICES

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Figure A.1 *Map of Bandelier National Monument. Courtesy of the National Park Service, <http://www.nps.gov/band/ppmaps/bandmap%2Epdf>.*



Figure A.2 *Aerial Photograph of Frijoles Canyon, Overlaid with Contour Lines. Cavate Groups A-M are marked in Red.*

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

APPENDIX B: FIELD SURVEY CONDITION FORM AND GLOSSARY OF TERMS

ARCHITECTURAL CONDITION ASSESSMENT BANDELIER NATIONAL MONUMENT

Area: Frijoles Canyon LA # Group: Room #

Date Examined by:

UNIT SUMMARY DATA

Unit type: cavate Orientation (facing): _____

Associated geological joints: yes / no Number of joints: _____

Context: isolated / cluster / contiguous Exposure: open / protected

Number of entrances: _____

Dimension of entrances / openings (measure all):

height (max) _____ cm. width (max): _____ cm.
 _____ cm. _____ cm.
 _____ cm. _____ cm.

Dimensions for a curvilinear or D-shaped plan (all measurements in metric; include in plan and section sketch):

- 1 diameter (max): _____ cm
- 2 diameter perpendicular to maximum: _____ cm.
- 3 height from floor to ceiling at center: _____ cm.

Dimensions for a rectilinear plan (metric; include in plan and section sketch):

- 1 length of each wall (max): _____ cm _____ cm _____ cm. _____ cm.
- 2 height from floor to ceiling at center (max): _____ cm

Sketch (complete on back)

Plan (indicate geologic joints)	Elevation (for each wall, include features)

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

ARCHITECTURAL CONDITION ASSESSMENT

BANDJER NATIONAL MONUMENT

Cavate building materials (circle all that apply): Rock - location: _____ Masonry - location: _____

Rock type: Tschirege tuff / Otowi tuff / other _____

Interior rock surface texture: undressed / eouited / pecked / obscured / indeterminate / other _____

Original masonry type: wet-laid / dry-laid _____

Original masonry stone type: Tschirege tuff / Otowi tuff / basalt / other: _____

Original mortar type: earth / indeterminate / other: _____

Masonry stabilization: yes / no Stabilization mortar type: earth / modified earth / Portland cement / other _____

Stabilization date(s): _____

Dimension of masonry walls:

Length: _____ cm Height: _____ cm

Width (upper): _____ cm (hasa): _____ cm

Features (circle all that apply):

firepit / floor ridge / large floor level niche / wall niche / slot / vigna holes /
loom anchors / smoke hole / vent / interior door / sooted ceiling / metal rest
/ upper loom supports /
other (describe): _____

Comments:

SURFACE FINISHES

General scheme for interior walls and ceiling (circle one):

	earthen finished walls and sooted rock ceiling
	earthen finished walls and unsooted rock ceiling
	sooted rock walls and ceiling
	sooted rock walls and earthen finished ceiling
	indeterminate
	other (describe): _____

Walls (cavate walls are defined by their degree of verticality up to 45° inclination from 90°)

Wall finish type (circle all that apply): extruded-smooth plaster / applied plaster / wash / sooted rock / unfinished

General colors (circle all that apply): red / brown / tan / white / gray / blue / green / black / other: _____

Maximum # of layers _____ Presence of sooted layers between earthen finishes: yes / no

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

ARCHITECTURAL CONDITION ASSESSMENT

BANDELIER NATIONAL MONUMENT

Finish scheme (uppermost visible)

A coverage: partial / full / indistinguishable B grouping: simple / complex / indeterminate

C. element(s) (circle all that apply): full wall / dado / field / aura / floor band / embellishment / indeterminate / other (describe): _____

Embellishment(s) present / absent

If present, include information on general quantity and description of embellishments in plaster and in rock (include motif(s) such as zoomorphic / anthropomorphic / geometric / other; application method(s) such as incised / applied / impressed / other; and colors):

Finish texture striated / finger or handprints / other (describe) _____

Earlier finish schemes yes / no

If yes, briefly describe

Ceiling (cavate ceilings are defined by their degree of verticality up to 45° inclination from 0°)

Predominant ceiling finish type applied plaster / wash / sooted rock / unfinished

Maximum # of layers _____ Presence of sooted layers between earthen finishes: yes / no

General color(s) (circle all that apply): red / brown / tan / white / gray / blue / green / other: _____

Finish scheme (uppermost visible)

A coverage: partial / full / indistinguishable B. grouping: simple / complex / indeterminate

C. element(s): aura, embellishment, other (describe) _____

Embellishment(s) present / absent

If present, include information on general quantity and description of embellishments in plaster and in rock (include motif(s) such as zoomorphic / anthropomorphic / geometric / other; application method(s) such as incised / applied / impressed / other; and colors):

Finish texture striated / finger or handprints / other

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

ARCHITECTURAL CONDITION ASSESSMENT

BANDELIER NATIONAL MONUMENT

Earlier finish schemes: yes / no

If yes, briefly describe:

Floor

Materials: earthen plaster / bedrock / obscured / other (*describe*): _____

Maximum # of layers: _____

Description (*surface treatments, stratigraphy, etc.*)

GENERAL COMMENTS:

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

ARCHITECTURAL CONDITION ASSESSMENT

BANDELIER NATIONAL MONUMENT

EXISTING CONDITIONS

Severity / Extent of condition (% of total existing surface area affected except for loss, which is % of total original) provide the following scores

0=Insignificant (<10%); 1=Low (10-25%); 2=Moderate (26-50%); 3=High (>50%)
and then multiply by 2 where indicated)

CONDITION	Int. Walls		Int. Ceiling		Int. Floor	Exterior	
	rock	finish	rock	finish	finish	Rock/ masonry	finish
loss of total original (x 2)							
partial loss (finishes only) (x 2)							
disintegration/friability (x 2)							
detachment (includes flaking / delamination / blistering / blind voids) (x 2)							
rock undercutting (x 2)							
structural cracking (x 2)							
non-structural cracking (rock) / map cracking (finishes)							
salts							
accretions							
mechanical damage / abrasion (x 2)							
graffiti / vandalism (x 2)							
biological growth							
vegetation							
other (describe)							
TOTAL (include score for total loss and total score for all conditions other than total loss)	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>

General condition comments (indicate which conditions appear to pose the greatest threat(s) to the resource):

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

BAND Architectural Condition Assessment TERMS

GLOSSARY OF

Area: Frijoles Canyon

LA #: Laboratory of Anthropology site classification number (see plans)

Group: classified as Groups A-M (Group B: no #, Group C: 50970; Group D: 13665; Group E: 13664; Group M: 50972)

Room #: as per plans and elevations

Date: date(s) of examination


Examined by: surveyor(s) full name


UNIT SUMMARY DATA:

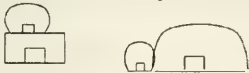
Unit type: *cavate*- cavities in the canyon walls enclosed on at least three sides that are primarily the result of excavation of the rock

Orientation (facing): compass directions (N, E, S, W, NE, NW, SE, and SW)

Associated geological joints: geological joints defining or intersecting the feature (interior and exterior), indicate yes or no; if yes, include number of joints

Context: *isolated*- isolated singular unit with no immediate adjacent neighbors or shared walls, ceilings, floors 

cluster- a group of two or more of the same units in close proximity 

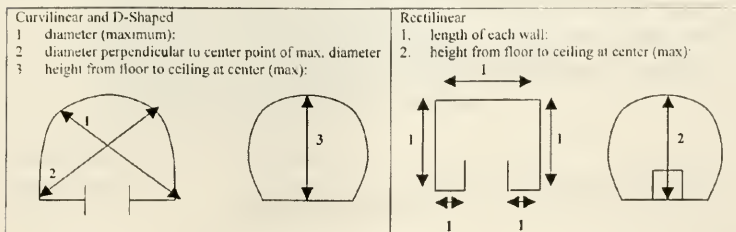
contiguous- a subcategory of clustered units where adjacent units are joined through a common interior opening/entrance 

Exposure: *open*- opening is $\geq 50\%$ of entrance wall
protected- opening is $< 50\%$ of entrance wall

Number of entrances: provide total number of extant entrances (an entrance is an original opening large enough for a person to pass through, not smoke holes or vents). If entrance wall is missing or damaged, and entrances cannot be observed, enter 0 with explanation (i.e. original entrance(s) have been eroded or lost).

Dimension of entrances / openings: record height and width of all entrances / openings in centimeters

Dimension of cavate: record cavate dimensions as described below



APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

BAND Architectural Condition Assessment TERMS

GLOSSARY OF

Sketch: sketch plan and elevations, indicate geologic joints (include dimensions)

Cavate building materials:

rock-modification of the living rock, usually through subtractive processes; provide general location (e.g. all walls)

masonry-rubble or worked / finished rock units laid dry or wet with mortar, provide general location (e.g. lining smoke hole, entrance)

Rock type: *Tschirege* tuff (gray in color, most cavates in Frijoles Canyon are in the lower unit of the Tschirege member)
Otowa tuff (tends to be red in color and less consolidated (welded) than the Tschirege member)

Interior rock surface texture: *undressed*- no tooling (discernable on exposed rock surface)
pointed-gouged, groove tooling
pecked-pounded, dimple tooling
obscured- concealed or damaged

Original masonry type: pertains to unstabilized, original masonry
wet-laid- with mortar between the stones
dry-laid- without mortar between the stones

Original masonry stone type: *Tschirege* tuff (gray)
Otowa tuff (red)
basalt (tends to be dark in color and very welded)

Original mortar type: self-explanatory

Masonry stabilization: indicate yes or no based on records and/or visual observation

Stabilization mortar type: *earth*
modified earth- earth with additive such Portland cement (gray), calcium aluminate (pink), or acrylic
Portland cement

Stabilization date(s): indicate if known, cite reference

Dimension of masonry walls: record length and width (top and bottom) of all walls in metric

Features: circle all that apply; definitions as per Toll (see attached)

SURFACE FINISHES

General scheme for interior walls and ceiling: self-explanatory

Wall Finishes

Predominant wall finish type:

extruded smooth plaster-mortar that extends beyond masonry courses and onto the surface of the wall, covering at least 3/4 of each masonry unit, does not apply to plaster on tuff; is often used as a surface leveling and filling technique, thickness can vary

applied plaster- a discrete layer or layers of plaster greater than 1mm thick applied over masonry or tuff, and which has been worked to create a continuous, relatively uniform surface

wash- a discrete layer or layers of thinly applied earthen finish, usually less than 1mm thick, which is applied directly over plaster, masonry, or tuff

sooted rock- soot deposited on the tuff (without earthen finishes)

unfinished- the intentional absence of a finish

General color(s): circle all visible colors

Maximum # of layers: maximum number of plaster and wash layers visible with the naked eye or with low magnification (spot not counted)

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

BAND Architectural Condition Assessment TERMS

GLOSSARY OF

Presence of sooted layers between earthen finishes: indicate yes or no

Finish scheme: this combination of fields describes the spatial coverage of the finishes and the grouping of elements that compose the surface scheme (the uppermost visible layer); this set of attributes relates to the original intent and execution of the finish application, as opposed to the existing remnants

A. first describe the coverage as either:

partial-the presence of one or more finish elements (see below) in combination with unfinished rock, the wall is not fully finished (including sooting)

full-the presence of one or more finish elements covering the entire wall, the wall is fully finished
indistinguishable- can't tell

B. then describe the grouping of elements as either:

simple-the presence of only one element defining the surface scheme

complex-the presence of two or more elements defining the surface scheme

C. lastly, indicate the types of elements (circle all that apply):

full wall-a layer or layers of earthen finish or soot that entirely cover the surface

band-as band of earthen finish or soot on the lower third or half of a wall that is finished differently than the rest of the wall

field-a band of earthen finish or soot on the upper third or half of a wall that is finished differently than the rest of the wall

aura-a finish of earth or soot around a doorway or other opening in the cavity; it is usually a different color than the rest of the wall

floor band-a band of earthen finish or soot applied to the lower 10-20cm of the wall; it can also be an extension of the material used to finish the floor

embellishment-a discrete detail or pattern of designs applied, incised, or impressed in earthen finish, soot, or rock

Embellishment(s): indicate if embellishments are present or absent; if present, provide the following descriptive information:

general number of embellishments in plaster and in rock: separate values for each

general description: this should include

• motifs (the type of representation that the embellishment most closely represents, such as

zoomorphic-having the form of an animal or bird

anthropomorphic-having the form of a human

geometric-having rectilinear or curvilinear lines

• application method used to create the embellishments such as:

incised-the small-scale incision of a motif or pattern into the finish or sooted tuff, created with a sharp tool, usually after the finish has dried

applied-the small-scale surface application of a wash, applied as a motif or pattern with the aid of a tool such as a yucca paint brush, stick, or fingertips to the wet or dry finish

impressed-the small-scale impression of a motif or pattern into the finish while it is still plastic and before it has dried, observed impressions include: maize cobs, potsherds, stick ends, fingertips, and handprints

• general colors such as red / brown / tan / white / gray / blue / green

Finish texture: *striated*-stippled, parallel grooves in finish
finger and handprints-finger and hand impressions

Earlier finish schemes: indicate yes or no and then briefly describe

Ceiling: same definitions as Wall Finishes

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

BAND Architectural Condition Assessment TERMS

GLOSSARY OF

Floor

Materials: self-explanatory

Maximum # of layers: maximum number of plaster visible with the naked eye or with low magnification on site

General description: describe layering sequence, etc.

EXISTING CONDITIONS:

Assess the type and severity of condition of the cavate interior walls, ceiling, floor, and exterior wall. Severity is the percentage of surface area affected for the rock and finish, except for loss, which is the percentage of total original. Assign a value of 0= **Insignificant (<10%)**; 1= **Low (10-25%)**; 2= **Moderate (26-50%)**; 3= **High (>50%)** and then multiply by 2 where indicated. At the end of the table, record the values for loss and the total sum of the other condition values

Conditions:

<i>loss-</i>	absence of original fabric based on total original extent of rock, masonry or finishes
<i>partial loss-</i>	loss of one or more layers from the existing finish, leaving earlier layers exposed, can occur only in multi-layered finishes
<i>disintegration/friability- detachment-</i>	granular disaggregation of the rock or finishes voids between finish layers, at the rock/plaster interface, or within the rock; includes <i>delamination</i> / <i>flaking</i> (the separation and lifting of discrete layers of finishes from each other; flaking is active deterioration and loss of thin fragments which are not necessarily confined to discrete layers as in delamination); <i>blistering</i> (localized, small scale swelling and/or rupturing of the finish layer; tends to occur in thin plaster layers) and; <i>blind voids</i> (voids or separation between plaster layers or at the rock/plaster interface which have no visible edges but which can be detected when a hollow sound is produced by tapping on the surface
<i>rock undercutting-</i>	the undermining of rock so as to leave an overhanging portion in relief; usually occurs on the ceiling near the entrance
<i>structural cracking-</i>	major (>1cm deep and/or 50cm long) linear discontinuities in the rock or masonry including geologic joints
<i>non-structural cracking-</i>	fractures of variable length and orientation in the rock or finishes that do not appear to be the result of structural settlement or movement or joints
<i>map cracking(finishes only)-</i>	fine pattern cracking over an area of the finishes; cracks usually penetrate only through a single finish layer
<i>salts-</i>	presence of salt crystals on surface of rock or finishes
<i>accretions-</i>	discoloration of the rock or finishes caused by the addition of a substance such as mud flow, animal excrement or other (does not apply to oxidation or soot)
<i>mechanical damage/abrasion- graffiti / vandalism-</i>	discrete areas of damage or loss caused by an external impact or force modern, intentionally inscribed or applied markings on the rock or finishes
<i>biological growth- vegetation-</i>	the presence of microflora (algae, fungi, and/or lichen) on the surface presence of higher plant forms or the roots thereof

General condition comments: indicate which conditions appear to pose the greatest threat(s) to the resource

APPENDIX B: FIELD SURVEY FORM AND GLOSSARY OF TERMS

BAND Architectural Condition Assessment TERMS

GLOSSARY OF

TREATMENT RECOMMENDATIONS:

Treatment priority:

<i>high priority-</i>	high priority for treatment due to significance of room (based on uniqueness of features, finishes schemes and/or embellishments), high percentage of intact structural materials, features and finishes, and low percentage of loss and/or deterioration of remaining materials (only a small percentage of rooms should fall into this category)
<i>medium priority-</i>	few unique features, finish schemes and/or embellishments, medium to high percentage of intact structural materials, features and finishes, and medium to low percentage of loss and/or deterioration of remaining materials
<i>low priority-</i>	no unique features, finish schemes and/or embellishments, low percentage of intact structural materials, features and/or finishes, and high percentages of loss and/or deterioration of remaining materials

Proposed treatment actions:

<i>none-</i>	self-explanatory
<i>backfill (full)-</i>	fully fill a cavate with granular material (sand or soil) as a long-term preservation action; this treatment requires detailed written and graphic documentation prior to filling
<i>backfill (partial)-</i>	protect earthen floors and fragile floor features by temporarily covering them with sand and geotextiles to a shallow depth
<i>cover with slash-</i>	obscure the entrance with slash (vegetation) to deter visitor use
<i>restrict access-</i>	close to visitor use
<i>finishes conservation (grouting / cleaning / reattachment / edging / other)-</i>	stabilize and/or clean prehistoric and historic architectural finishes; work must be undertaken by a professional conservator
<i>graffiti mitigation-</i>	obscure graffiti by infilling or inpainting
<i>animal or insect control-</i>	eliminate animal and/or insect invasion (i.e. by filling rodent holes, screening areas to deter bee or wasp nesting)
<i>drainage control-</i>	prevent water from infiltrating or flowing directly onto the resource; actions may include installation of silicone drip lines, diversionary berms, protective shelters, etc.
<i>masonry stabilization-</i>	stabilize wall or features; actions may include replacing stones, repointing, and crack stabilization
<i>monitor-</i>	photograph and conduct regular visual comparative assessments to determine rate of change over time; assessment should make use of past documentation including historic photographs, reports, drawings, etc., pertaining to the area
<i>documentation-</i>	further documentation recommended, in most cases due to severe deterioration of surfaces and features

Safety hazard: indicate if public health risks exist due to dangerous conditions resulting from past or actively occurring deterioration, if so, describe the threats

Comments: prioritize treatment actions

PREVIOUS DOCUMENTATION:

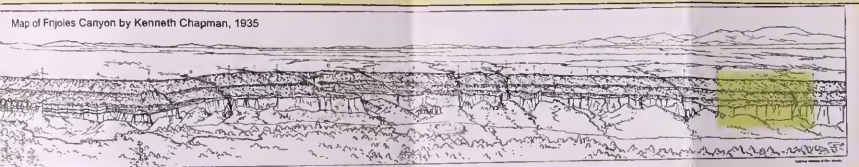
Cite previous and current reports, publications, photographs, drawings, etc.

Conduct photographic comparison between the image and the current appearance of the cavate

APPENDIX C, Layout 1

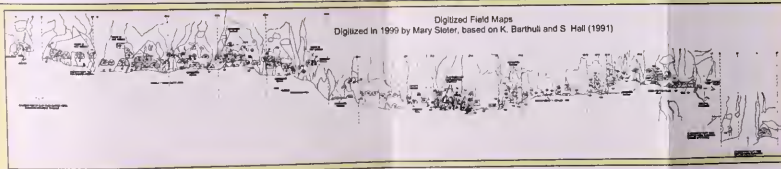
Three Methods of Describing the Landscape of Frijoles Canyon (Group M Highlighted in Yellow.)

Map of Frijoles Canyon by Kenneth Chapman, 1935



No. 3. SWITZERLAND WALL OF SITE IN LOS PEQUEÑOS


Digitized Field Maps
Digitized in 1999 by Mary Slater, based on K. Barthuli and S. Hall (1991)



Cavate Elevations, Imported from Vector Drawing

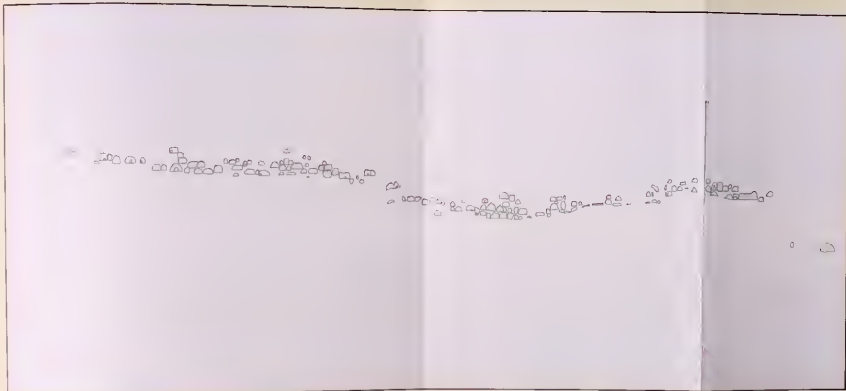


Legend

 Digitized Cavate Elevation

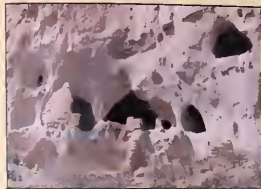
APPENDIX C, Layout 2

Cavate Elevation Image Imported into the GIS



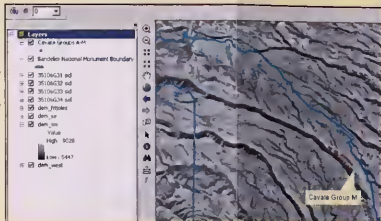
The Cavate Elevation drawings were imported into the GIS as individual polygons, and assigned the appropriate Cavate Identification number

APPENDIX C, Layout 3
Information Presented at 3 Different Scales



Landscape Overview of
Frijoles Canyon.

Cavate Groups A-M are
displayed over aerial
orthophotos of the
canyon.

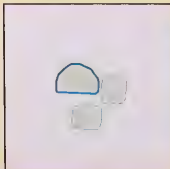


Cavates of Panel J. Middle Scale of Information



Photograph of
Panel J displayed
with a middle scale
of display

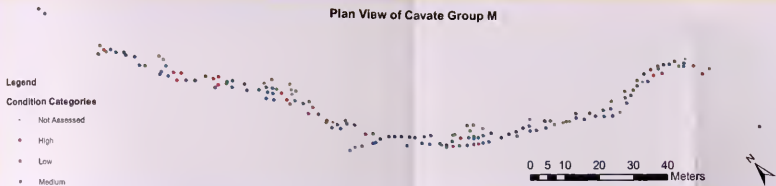
Cavate MJ098
Information contained in
the attribute table associated
with cavate MJ098 is
highlighted in blue



Cavate ID	TOTL_AREA	CUMD	SUBSTRATE	COMMENTS	STATUS
MJ101	12	12	Cave		Open
MJ113	6	2	Cave		Open
MJ136	13	2	Cave		Protected
MJ265	88	2	Ceramics		Protected
MJ278	5	1	Cave		Open
MJ302	5	2	Ceramics		Protected
MJ125	6	1	Cave		Open
MJ079	16	1	Cave		Protected
MJ093	32	4	Ceramics		Open
MJ110	6	1	Cave		Open
MJ098	2	1	Cave		Open
MJ115	12	1	Cave		Open
MJ145	6	1	Cave		Open
MJ146	6	1	Cave		Open

APPENDIX C, Layout 4
Distribution of Total Condition Categories in Cavate Group M

Plan View of Cavate Group M



Elevation View of Cavate Group M



Cavate Elevations Digitized by Mary Slater, based on K. Barthull and S. Heil, 1991

APPENDIX C, Layout 5

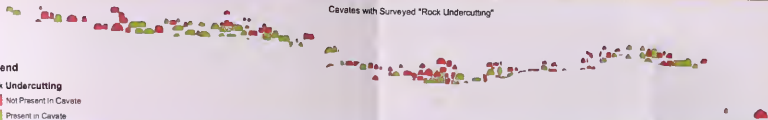
Presence of Surveyed Conditions: Graffiti, Mechanical Damage, and Structural Cracking

Cavates with Surveyed "Rock Undercutting"

Legend

Rock Undercutting

- Not Present in Cavate
- Present in Cavate

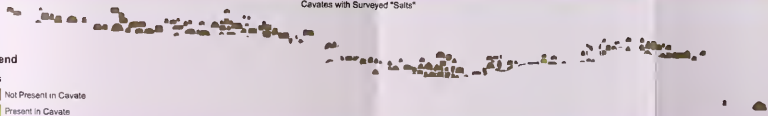


Cavates with Surveyed "Salts"

Legend

Salts

- Not Present in Cavate
- Present in Cavate

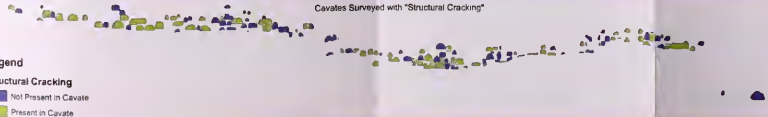


Cavates Surveyed with "Structural Cracking"

Legend

Structural Cracking

- Not Present in Cavate
- Present in Cavate



APPENDIX C, Layout 6

Presence of Surveyed Conditions: Graffiti, Mechanical Damage, and Vegetation

Cavates with Surveyed "Graffiti"

Legend

Graffiti

- Not Present in Cavate
- Present in Cavate



Cavates with Surveyed "Mechanical Damage"

Legend

Mechanical Damage

- Not Present in Cavate
- Present in Cavate

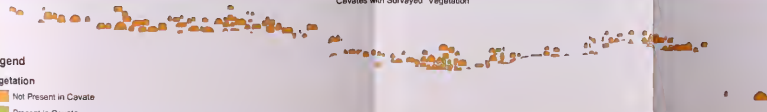


Cavates with Surveyed "Vegetation"

Legend

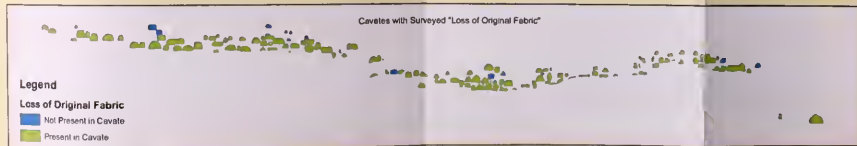
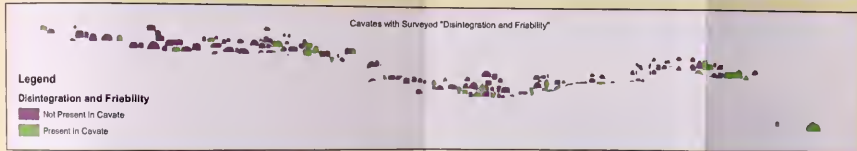
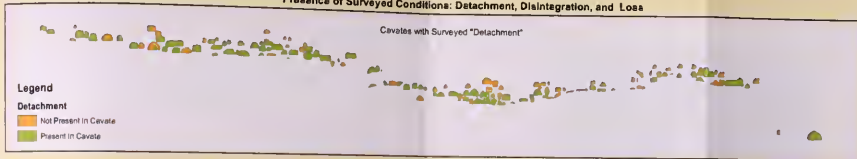
Vegetation

- Not Present in Cavate
- Present in Cavate



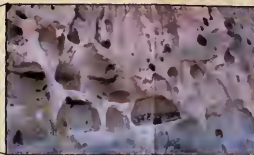
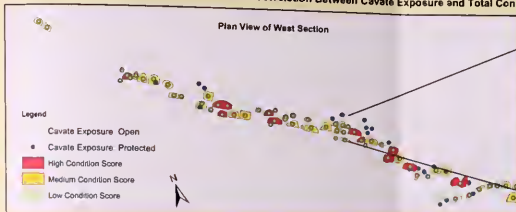
APPENDIX C, Layout 7

Presence of Surveyed Conditions: Detachment, Disintegration, and Loss

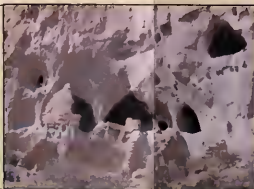


APPENDIX C, Layout 8

Correlation Between Cavate Exposure and Total Condition Score



Panel E Cavates
Protected due to niche in cliff face

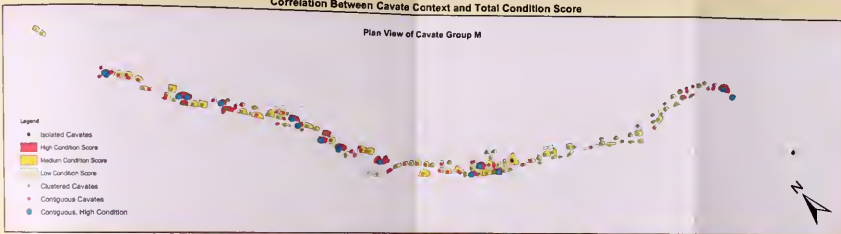


Panel J Cavates
Cavates considered "protected"
due to constructed masonry walls

APPENDIX C, Layout 9

Correlation Between Cavate Context and Total Condition Score

Plan View of Cavate Group M



Cavate MJ090
Contiguous Context, High Condition



Cavate MJ099
Contiguous Context, High Condition



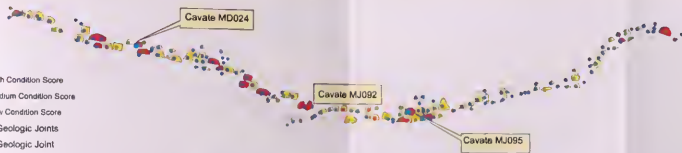
Cavate MQ160
Contiguous Context, High Condition

APPENDIX C, Layout 10
Correlation Among Geologic Joints and Total Condition Score

Plan View of Cavate Group M

Legend

- High Condition Score
- Medium Condition Score
- Low Condition Score
- 0 Geologic Joints
- 1 Geologic Joint
- 2 Geologic Joints
- 2 Geologic Joints, High Condition



Cavate MD024
2 Geologic Joints, High Condition



Cavate MJ092
2 Geologic Joints, High Condition

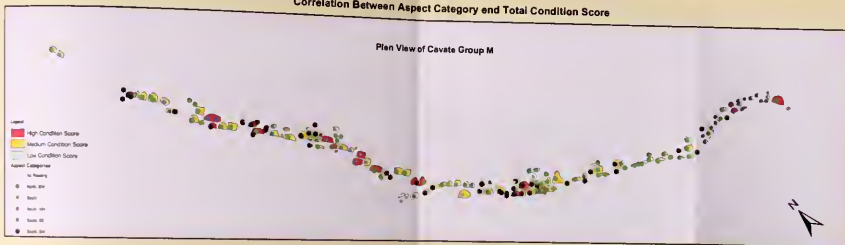


Cavate MJ095
2 Geologic Joints, High Condition

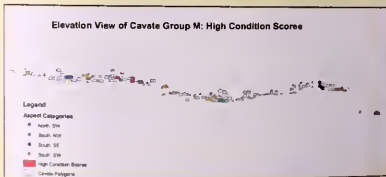
APPENDIX C, Layout 11

Correlation Between Aspect Category and Total Condition Score

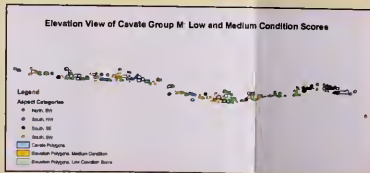
Plan View of Cavate Group M



Elevation View of Cavate Group M: High Condition Scores

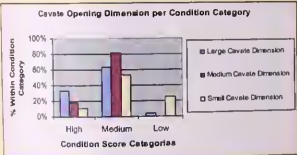
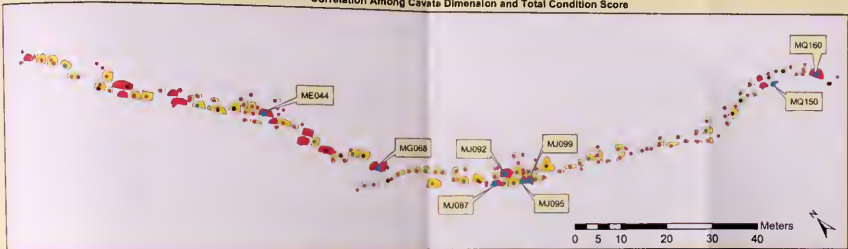


Elevation View of Cavate Group M: Low and Medium Condition Scores

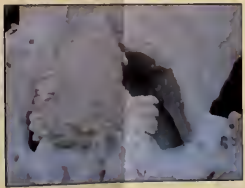


APPENDIX C, Layout 12

Correlation Among Cavate Dimension and Total Condition Score



Most of the cavates in the High Condition group have large opening dimensions. Many cavates with small opening dimensions fall within the low condition category.



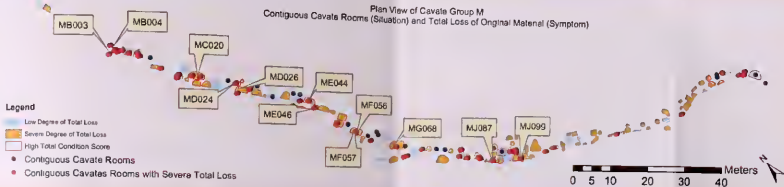
Cavate MJ092
Large Opening Dimensions, High Condition Score



Cavate MJ095
Large Opening Dimension, High Condition Score

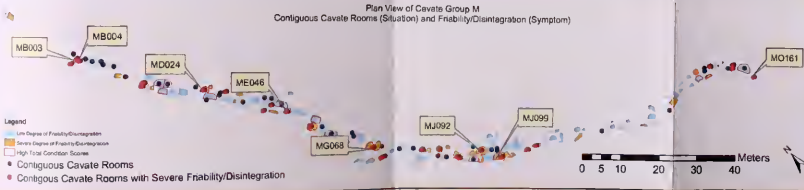
APPENDIX C, Layout 13
Correlation Between Contiguous Cavate Rooms, Total Loss of Original Fabric, and Friability/Detachment

Plan View of Cavate Group M
 Contiguous Cavate Rooms (Situation) and Total Loss of Original Material (Symptom)



There are twelve cavate rooms with a severe score recorded for total loss of original fabric, and fall into the high condition score category

Plan View of Cavate Group M
 Contiguous Cavate Rooms (Situation) and Friability/Disintegration (Symptom)

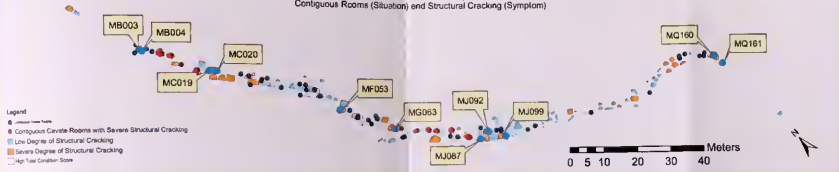


There are eight contiguous cavates with severe friability/disintegration scores, and fall into the high condition score category.

APPENDIX C, Layout 14

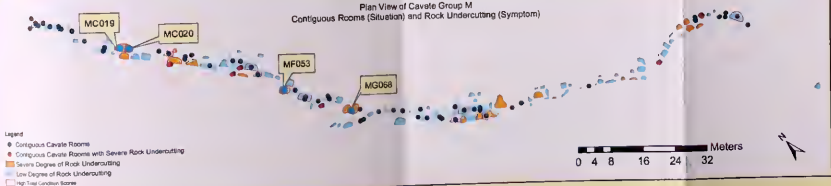
Correlation Between Contiguous Cavate Rooms, Rock Undercutting, and Structural Cracking

Plan View of Cavate Group M
Contiguous Rooms (Situation) and Structural Cracking (Symptom)



Eleven cavates are contiguous with a severe score recorded for structural cracking, and fall into the high condition score category.

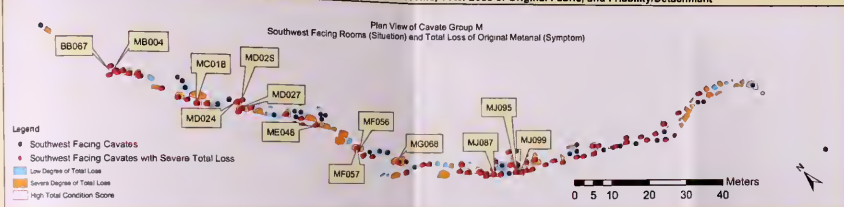
Plan View of Cavate Group M
Contiguous Rooms (Situation) and Rock Undercutting (Symptom)



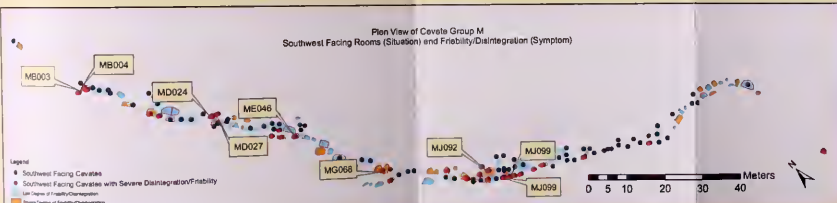
Four cavates are contiguous, with a severe score for rock undercutting, and fall into the high condition score category.



APPENDIX C, Layout 15
Correlation Between Southwest Facing Cavate Rooms, Total Loss of Original Fabric, and Friability/Detachment

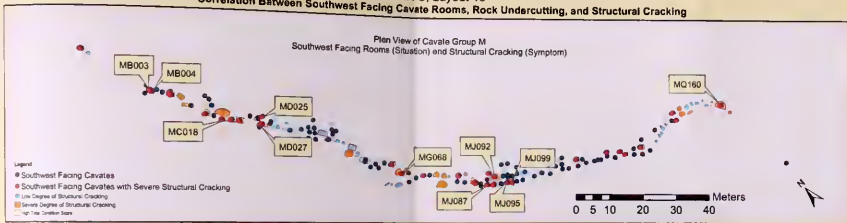


Thirteen cavates face southwest with a severe score recorded for total loss of original fabric, and fall into the high condition score category.

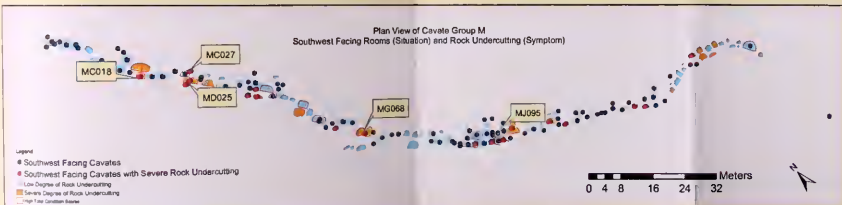


Nine cavates face southwest, with severe friability/diintegration scores, and fall into the high condition score category.

APPENDIX C, Layout 16
Correlation Between Southwest Facing Cavate Rooms, Rock Undercutting, and Structural Cracking

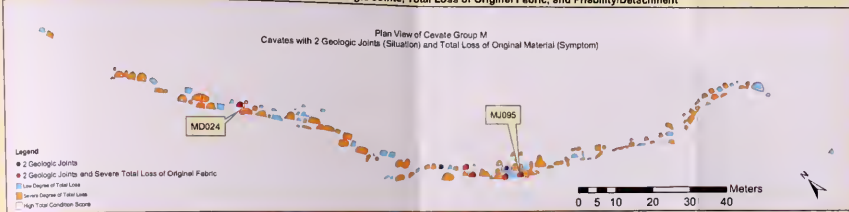


Eleven cavates face southwest with a severe score recorded for structural cracking, and fall into the high condition score category

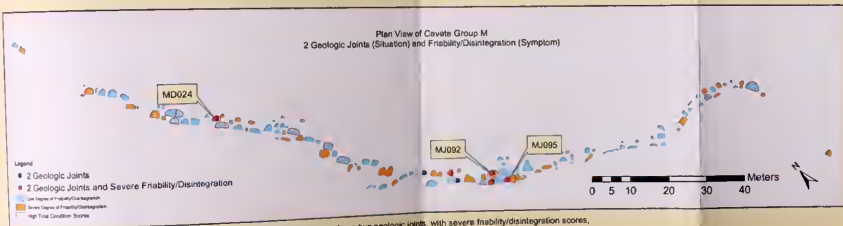


Five cavates face southwest, with a severe score for rock undercutting, and fall into the high condition score category.

APPENDIX C, Layout 17
Correlation Between 2 Geologic Joints, Total Loss of Original Fabric, and Friability/Detachment



Two cavates have two geologic joints with a severe score recorded for total loss of original fabric, and fall into the high condition score category



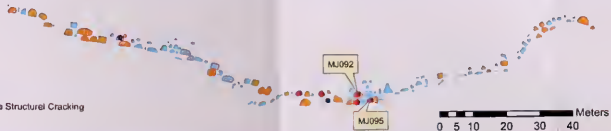
Three cavates have two geologic joints, with severe friability/disintegration scores, and fall into the high condition score category.

APPENDIX C, Layout 18
Correlation Between 2 Geologic Joints, Rock Undercutting, and Structural Cracking

Plan View of Cavate Group M
 2 Geologic Joints (Situation) and Structural Cracking (Symptom)

Legend

- 2 Geologic Joints
- 2 Geologic Joints and Severe Structural Cracking
- Low Degree of Structural Cracking
- Severe Degree of Structural Cracking
- High Total Condition Score

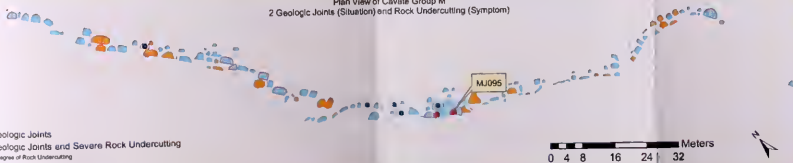


Two cavates have 2 geologic joints, a severe score recorded for structural cracking, and fall into the high condition score category

Plan View of Cavate Group M
 2 Geologic Joints (Situation) and Rock Undercutting (Symptom)

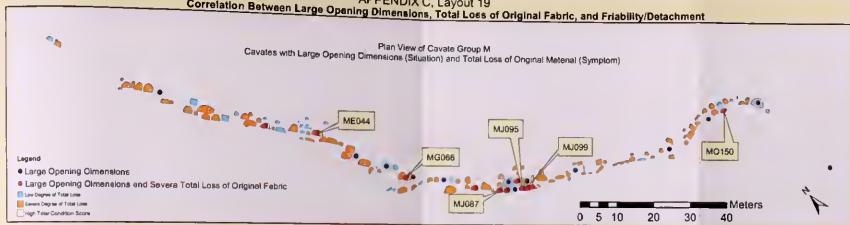
Legend

- 2 Geologic Joints
- 2 Geologic Joints and Severe Rock Undercutting
- Low Degree of Rock Undercutting
- Severe Degree of Rock Undercutting
- High Total Condition Score

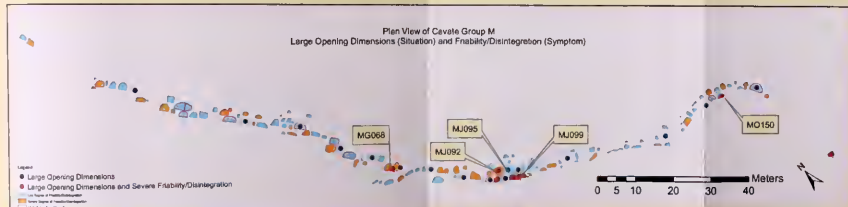


One cavate has two geologic joints, with a severe score for rock undercutting, and a high total condition score

APPENDIX C, Layout 19
Correlation Between Large Opening Dimensions, Total Loss of Original Fabric, and Friability/Detachment

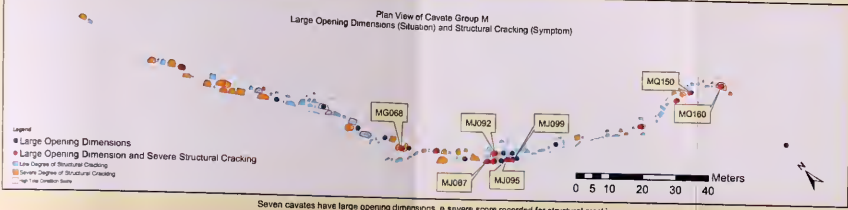


Six cavates have large opening dimensions with a severe score recorded for total loss of original fabric, and fall into the high condition score category

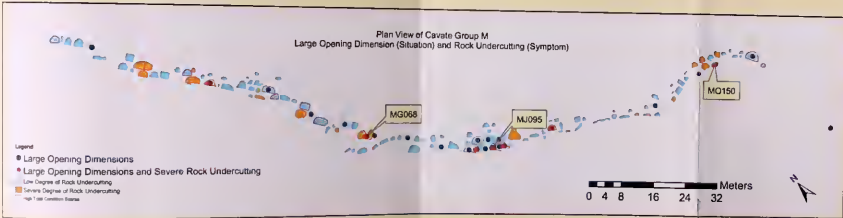


Five cavates have large opening dimensions with severe friability/disintegration scores, and also fall into the high condition score category.

APPENDIX C, Layout 20
Correlation Between Large Opening Dimensions, Rock Undercutting, and Structural Cracking



Seven cavates have large opening dimensions, a severe score recorded for structural cracking, and fall into the high condition score category



Three cavates have large opening dimensions, with a severe score for rock undercutting, and a high total condition score.

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